2015/2050

GEORGIA STATEWIDE TRAVEL DEMAND MODEL REPORT

September 2019

PREPARED FOR

GDOT Office of Planning

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1. INTRODUCTION AND BACKGROUND

This report describes the development and updates of the Georgia Statewide Travel Demand Model (GSTDM), which has been done by the Georgia Department of Transportation (GDOT) Office of Planning and its consultant, HNTB Corporation (hereinafter referred as "the model development team"). This report is intended for readers who have a basic understanding of travel demand modeling concepts. The model is Version 1.0 dated June 2019 with a base year of 2015 and forecast year of 2050.

1.1 WHAT IS TRAVEL DEMAND MODELING?

Travel demand modeling is an essential component of transportation planning process for defining future policies, goals, investments, and designs to prepare for future needs to move people and goods to various destinations.

Regional or statewide travel demand models (TDMs) provide the scale needed to analyze the benefits of transportation investments. The critical questions surrounding any transportation investment include not only "Where is a facility needed?" but also "When and why is a facility needed?" These questions can be answered through the regional perspective provided by larger-scale TDMs. The process of travel demand forecasting uses what we know about the existing world to predict what conditions will be like in the future. It is a projection based on empirical data and foreseeable circumstances.

Most TDMs utilize a traditional four-step approach to estimate travel demand and patterns, how many trips will be generated, where they are going, what modes they are using, and which routes they will use. In the broadest sense, the TDM consists of three elements: model inputs, a series of modules conducting mathematical procedures, and model outputs.

1.1.1 Model Inputs

Model inputs are based upon the roadway system, land use, and demographic and socioeconomic (SE) data. SE data, such as population, household, and employment by industry, represents land use. Future year projections of SE data are based on existing land uses including land development, as well as statewide or regional forecasts of population, household, and employment. Future year forecasts also considered planned major transportation improvements, including roadway capacity improvements and multi-model transportation improvements.

1.1.2 A Series of Mathematical Procedures

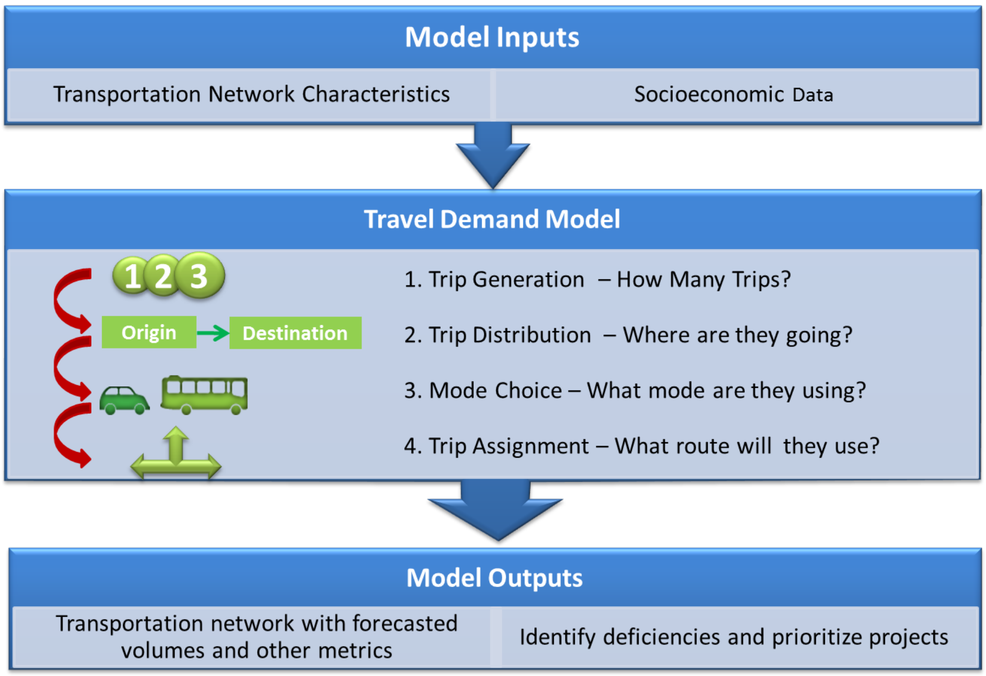
TDMs ultimately forecast future traffic demand using four steps: 1) trip generation, 2) trip distribution, 3) mode choice, and 4) trip assignment. It is called the "four-step approach" or "four-step model" which is the most common method used in the United States. This is an aggregate sequential process with four basic steps:

1. Trip Generation – How many trips will be made?
2. Trip Distribution – Where will the trips go?
3. Mode Choice – What modes of transportation will the trip use?

4. Trip Assignment – What routes will the trips take?

Figure 1-1 illustrates the standard four-step modeling process, highlighting typical major input data elements, model components, and model outputs.

Figure 1-1: Four-Step Modeling Process



1.2 GEORGIA STATEWIDE TRAVEL DEMAND MODEL (GSTDM)

The purpose of the GSTDM is to develop analysis tools that have the capacity to analyze the impact of the modal diversion for people and goods, major changes in land use and economic policies, and alternative modes of person travel. The model also provides for the analysis of the impact of future transportation infrastructure investments and strategies. The model may also be used to assist with future Metropolitan Planning Organization (MPO) model updates, to test various project/corridor alternatives, and to update the Georgia Department of Transportation (GDOT) statewide transportation plans (SWTP). The GSTDM can provide external travel for the MPO models and forecast future travel demand both in pass-through and internal-external travel. It can assist with assessing the impact of large-scale corridor improvements such as interstate widening, construction of new facilities, and so on. It can also help perform policy level analysis such as freight diversion analysis between truck and rail and analysis of toll facilities. The model was developed based on the most current data sources available at the time. The current model is limited by the existing data available for long-distance travel especially internal to external travel but can be enhanced as more data become available.

It should be noted that the GSTDM is not appropriate for the analyses listed below, and particularly for travel within MPO model areas. The individual MPO models should be used for these types of applications.

- Detailed personal and vehicle travel patterns and demands within MPO areas
- Identification of future bottlenecks within MPO areas
- Detailed intermodal freight movements within MPO areas

Additionally, GSTDM outputs should not be used directly for

- Estimation of peak hour design traffic volumes
- Evaluation of operational improvements
- Determination of project logical termini

1.3 MATERIALS AVAILABLE FOR QUICKLY USING THE GSTDM

A step-by-step reference guide is developed to enhance understanding for the general planning needs of transportation analysts using GSTDM.

1.3.1 User Guide

This document outlines step-by-step guidance to perform model runs using GSTDM. The GSTDM is implemented in Cube platform, a software that includes modes of transportation to create a multimodal travel demand forecast. This User Guide provides steps to open the model interface, check the model variables, run the model scenarios, and check input and output files. The User Guide is for users who are familiar with Cube and have a basic understanding of travel demand models. The User Guide is provided in Appendix A.

1.3.2 Quick Reference Guides

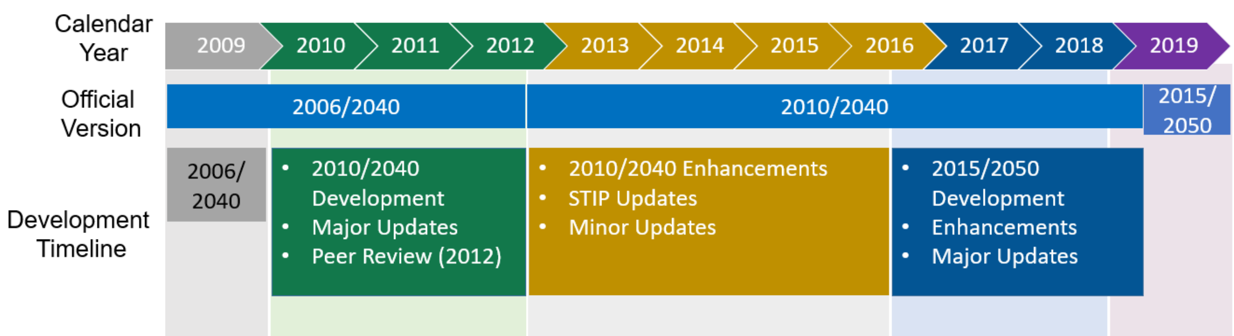
Quick Reference Guides have been developed for users who do not need to perform travel demand model runs but are interested to explore or use the model input and output network data. The Quick Reference Guides provide step-by-step instructions for users to open the input and output networks in Cube and ArcGIS/ArcMap to assess the data. Quick Reference Guides are provided in Appendix B.

2. UPDATES AND ENHANCEMENTS

The first version GSTDM was previously completed in 2010, with the base year 2006 and forecast year 2040. With the availability of additional data, specifically the 2010 Decennial Census, the base year for the model validation and calibration was updated to the year 2010. From 2013 to 2016, few revisions were made to the base year 2010 network and the future year 2040 network, including updating 2040 E+C network with the latest project list. A peer review[1] was conducted in September 2012 to assess this initial version of the GSTDM. The peer review set the stage for many of the updates and enhancements that have been applied to the GSTDM. The enhancements were implemented as the 2010 base year model was updated to 2015 and forecast year was updated to 2050. These updates and enhancements were intended to meet the emerging need for a newer version of the model that can reflect the most current travel conditions and support many other planning activities within GDOT and other planning agencies.

This chapter includes two major components: 1) the base year 2015 and forecast year 2050 update and 2) the 2010/2040 GSTDM enhancements based on the 2012 the peer review recommendations. Figure 2-1 represents the model version changes since 2010 and includes the time periods when the update activities were performed.

Figure 2-1: Model Version Changes and Timeframe



The first subsection below summarizes the recommendations of the peer review. The subsequent subsections summarize updates and enhancements related to the roadway network, TAZs, base year, freight, and other components. The updates and enhancements are further discussed in relevant chapters of the report.

[1] Federal Highway Administration. *Georgia Department of Transportation (GDOT). Statewide Travel Model Peer Review Report*. TMIP Report FHWA-HEP-13-031, September 2013.

2.1 SUMMARY OF PEER REVIEW RECOMMENDATIONS

Travel Model Improvement Program (TMIP) provides assistance to fund a peer review for state DOTs and planning agencies by inviting expert peer review panel to better inform the agencies travel demand model and provide expert comments on the model's state of the art and practice. GDOT Statewide Travel Demand Model peer review was conducted in September 2012. The goal of the peer review included identification of model deficiencies, recommendations for model enhancements, and guidance on model applications.

Table 2-1 below lists all the recommendations that resulted from the peer review along with their current status as of the release of the 2015 version of the GSTDM. The table notes whether the peer review recommendation was applied during the 2015 model update or not. Text following the table describes each recommendation and its application in further detail. Also see Appendix C for a scorecard that details, in even more depth, the various GSTDM component recommendations.

Table 2-1: Peer Review Recommendations and Status

Timeframe	Peer Review Panel Recommendations on 2006/2040 Georgia Statewide Travel Demand Model (GSTDM)	Corresponding Improvements that have been done in the post 2010/2040 GSTDM enhancement and the current 2015/2050 GSTDM update	
Short Term (one to two years)	Identify intent and objectives for model application: 1) The statewide analysis needs include truck demand, long-distance travel, and long-range planning.	Yes	The truck model was updated to include non-freight trucks, the model specification was simplified as suggested in the peer review, and the mode choice routine was updated to be more responsive to changes in relative competitiveness between the truck and rail modes.
	Identify intent and objectives for model application: 2) The key policies in the model should include pavement preservation, high- speed rail, and toll roads.	No	Pavement preservation is likely to be considered during operational analysis. High- speed rail has not been implemented in Georgia yet. The toll roads currently are all in the Atlanta region and toll models usually utilize the time of day and peak direction, which requires more detail than available in the statewide model.
	Identify intent and objectives for model application: 3) The complex and important behavior should include trucks, non-resident travel, and intercity travel.	Yes	The truck model was updated, the long-distance trip rates were also updated to use travel distance rather than time.
	Improve model documentation	Yes	The model documentation describes in detail the updates and enhancements applied in the GSTDM. It was improved by creating a general brochure, quick users guide, and the present model validation report. The brochure was created to provide general planners and GDOT management an overview of the GSTDM, including the model purpose, input data, model process, model outputs, and model applications. A quick user guide was developed for transportation planners who are not familiar with travel demand models. The user guide provides instructions on using CUBE or ArcGIS for opening the input and output networks as well as outlines the steps to run the model from Cube. The present model validation report for the 2015 update includes more details on the data source, data processing, and model validation performance.
	Further validate individual model components	Yes	The 2015 GSTDM has further validated individual model components as the peer review suggested. Details of the validation are provided in Chapter 8 of this documentation. Specific recommendations that were applied included: validation of distribution based on CTPP/ACS district-to-district origin-destination (OD) flows, comparison via OD scattergrams, and validation of the truck model after reducing its over-specification.
	Simplify and streamline the model where possible	Yes	The catalog was simplified via flow chart revisions and removal of unnecessary keys. SE data category reconciliation simplified model inputs (see Chapter 4). The freight trip generation and distribution specification were simplified as the original was considered over-specified based on the data at hand.
	Integration with REMI	Yes	REMI region information was included in the input network and output results to improve an efficient process to compare model inputs to REMI data and to summarize model outputs by REMI regions.
	Review NCHRP 08-84 Rural and Long-Distance Travel Parameters for Statewide Models	Yes	Long -distance was originally defined as trips with travel time more than 75 minutes. It was redefined based on the distance of 50 miles. The long-distance trip rates were reviewed and re-estimated using the 50-mile threshold.
Mid Term (three to five years)	Examine balance of network detail and TAZ detail	Yes	In the 2015 update, the input network has been greatly expanded to include minor arterials and above. Interchanges along all interstates have been reviewed and updated to the base year condition. TAZ boundaries have also been updated to accommodate the improved input network. SE data has been reconciled to use the NAICS categories and streamlined to four categories. Detailed statistics for all the updates are provided in Chapters 3 and 4.
	Incorporate FAF and ATRI data	No	This was not undertaken given available time and budget, but eventual acquisition of ATRI data may enhance the non-freight components that were added to the model. Currently, the approach used was to borrow from the examples in other states such as Wisconsin and Mississippi. FAF data is an alternative to TRANSEARCH and may be considered in the next major model update.
	Investigate over-specification in the freight model	Yes	The geographic based over-specification that included use of three separate sets of generation rates and distribution friction factors for Georgia I-I, Georgia – neighboring I-E/E-I, and Georgia – distant state I-E/E-I was removed. Instead, a simplified specification based on 2013 TRANSEARCH tonnage to employment for all geographies was used for the current freight model. Outliers were also kept but were handled via special generator functionality. Details are provided in Chapter 5.
	Consider two-way integration with the Atlanta Regional Commission (ARC) model	No	At the time of the 2012 peer review, ARC model was a 4-step model; however, in 2016 it was upgraded to activity-based model (ABM). There are still ongoing changes in ABM that include changes in zones and network. The integration between the two models would need significant efforts and therefore was not carried out in the current update.
	Examine pivoting off base year commodity flows or using TRANSEARCH forecasts	Yes	TRANSEARCH forecasts are unavailable for Georgia in the dataset used. Consequently, the GSTDM forecast year tonnages use the base year validated estimated tonnages from TRANSEARCH as the baseline and then use model SE growth to arrive at horizon year tonnage at the external locations. The regular

Timeframe	Peer Review Panel Recommendations on 2006/2040 Georgia Statewide Travel Demand Model (GSTDM)	Corresponding Improvements that have been done in the post 2010/2040 GSTDM enhancement and the current 2015/2050 GSTDM update	
			freight trip generation functionality handles the internal GA trip generation using the provided GA 2050 SE data applied to the validated generation model from the base year. Details are provided in Chapter 5.
	Examine multiple scenarios for freight forecasts, ranging from low to medium to high, and multiple forecast years	No	This recommendation was not implemented as it is not a part of model development. However, it serves as a foundation for various studies like statewide plan or freight, and therefore could be done upon request when the need arises.
	Include further stratifications by income and value of time, particularly with regard to passenger rail or pricing studies	No	This has not been implemented yet due to absence of passenger rail in Georgia and pricing studies require development of toll models that utilize the time of day and peak direction, which requires more detail than available in the statewide model.
	Consider destination choice models	No	Destination choice for distribution is the next likely step for the GSTDM but was not undertaken for this effort. It would require additional data that is not readily available.
	Examine time of day assignment	Yes	A time of day function model for AM and PM peak periods was developed for the current GSTDM. Details are provided in Chapter 9.
	Establish carrier surveys and a data program	No	This activity can be considered but was not undertaken given time and budgetary resources.
Long Term	Acquire additional household survey data with a focus on obtaining rural information	No	The latest household survey efforts, 2017 National Household Travel Survey add-on data effort in Georgia was focused on MPO and small urban areas. Rural area travel surveys can be done but would require additional funding. It should be considered during the next major model update.
	Explore statewide dynamic traffic assignment	No	This could be a long-term goal, as dynamic traffic assignment requires significant efforts and changes to the model to ensure it is accurate at a state level.
	Explore land-use forecasting and allocation modeling, including PECAS, urbanism, or simpler model	No	This recommendation was not implemented due to the significant effort that would be required. Currently, only the Atlanta region is maintaining and updating a land use forecasting model, which supports the inputs for ARC's ABM model. All other regional commissions utilize simpler processes to estimate the land use and SE data.
	Develop discrete mode choice for all purposes	No	This would be a significant effort and depends on a variety of data including onboard surveys and data on trip making characteristics. This could be considered as an improvement in the long term.
	Consider rebuilding the model from scratch to a new trip- or activity-based model	No	Activity-based models requires significant time, effort, and resource in term of capital and labor. ABM development experience from other states should be obtained for GDOT to make decision if and/or when an ABM model should be built.
	Investigate supply chain freight modeling	No	This would require considerable effort but should be kept as an option when the budget and planning environment allows.

2.2 2010 TO 2015 BASE YEAR MODEL UPDATES

Based on the enhanced 2010/2040 model, a significant model update effort has been undertaken during 2017 and 2018. The following changes were made to the 2010/2040 model and the outcome represents the updated 2015/2050 GSTDM. This section described the updates to the 2010 base year highway network that contributed to a final 2015 base year network.

2.2.1 Highway Network

Extensive updates were applied to the highway network as part of the 2010 to 2015 update effort. The major updated model input components are summarized below.

- Number of lanes were updated based on 2015 roadway number of lanes.
- Functional classification was updated based on 2015 roadway functional classification identified by GDOT.
- Additional roadways were added to the network to ensure roadways with functional classification of minor arterials and above were represented. Collectors were also coded if required for roadway connectivity.
- Roadway mileage was checked against GDOT's 445 Report – Mileage by Route Type and Functional Classification.[2,3]
- Centroid connectors were revised to better follow actual roadway access to the network. Any inappropriate centroid connector connections to interstates or freeways were also removed as necessary.
- Link distance was checked and revised as necessary.
- Dangling links in the 2010 input network were removed or connected to other links.
- Speed and capacity lookup tables were updated.
- Interstate interchanges were thoroughly reviewed within Georgia and coded to reflect the 2015 conditions.

Various data sources were utilized to update the input data. Chapter 3 provides additional information and statistics of the updated input data.

2.2.2 TAZ System

Another building block of the GSTDM, TAZs were also updated. Major updates are summarized below.

- TAZs were added, deleted, or merged and boundaries were revised to match Census boundaries and other barriers.
- TAZs were renumbered. TAZs belonging to any given MPO were clustered together and assigned continuous numbering. The Cartersville and Gainesville-Hall MPOs were added. The numbering system starts for the 16 MPOs first followed by the rest of Georgia and externals.
- Area types were redefined using the ranges of population and employment density.

[2] http://www.dot.ga.gov/DS/Data#tab-2
[3] http://www.dot.ga.gov/DriveSmart/Data/Documents/400%20Series/445/DPP445_2015.pdf

- Socioeconomic employment categories were reconciled.

Chapter 4 provides additional information on TAZ system updates and its associated socioeconomic data updates.

2.2.3 2015 Base Year Socioeconomic Data

Beyond the other major structural updates, adjusting the base year from 2010 to 2015 primarily involved changes to the SE data. SE data updates, described in Section 4.2, included using 2015 Census American Community Survey (ACS) 5-Year Estimates at Census tract level population data for population, household and median household income, and 2015 employment data, from multiple data source including U.S. Bureau of Economic Analysis (BEA), Department of Labor (DOL) and InfoGroup data purchased by GDOT.

2.2.4 Freight Model

The 2010/2040 version of the GSTDM included a freight model that was estimated from the latest 2013 TRANSEARCH, but used derived employment data based on REMI control totals. For the model update from 2010 to 2015, an updated employment dataset using InfoGroup data was used as the independent variable in the estimation database. This database was then used for the development of the freight model that would be sensitive to changes in the population, employment, and transportation networks in Georgia.

2.3 MODEL ENHANCEMENTS

2.3.1 Enhancement of Long-Distance Travel Forecasts

One key peer review recommendation was to improve the definition of long-distance trips. The GSTDM previously used a 75-minute threshold between short- and long-distance trips, which defined trips with more than 75 minutes travel time as the long-distance trips. Such a time-based cutoff is unusual and can lead to the same origin-destination set being classified as short- or long-distance depending on the model run. To improve the model's ability on trip generation, the model development team established a 50-mile long-distance trip threshold based on related research and experience from other statewide travel demand models. Further details are provided in Section 7.1.2.

2.3.2 Development of Time-of-Day Assignment

Applications of the GSTDM often involve questions regarding time-period specific travel, which a purely daily model would have limited ability to address. A time-of-day assignment model was developed as a post-processor to the daily model, as a result the time-of-day post processor enhanced the GSTDM and extended the application of the GSTDM to support more planning needs. This improvement is discussed in Chapter 9.

2.3.3 Updates to Catalog

The model is implemented in Cube Catalog, in association with Application Manager, to ease model usage utilizing the graphical user interface. Updates have been reflected within this structure.

2.3.4 Networks in Geodatabase Format

Networks are available in geodatabase format for reference. This enhances the accessibility of the data for users who may be more familiar with or have access with GIS (geographic information systems) software packages.

2.3.5 Better Integration with MPO Travel Demand Models

The integration of the GSTDM with the MPO models focused on the model input data updates. The SE data was in different formats in the 2010/2040 GSTDM and MPO models. A SE data reconciliation effort was done to include the review of SE data categories between the NAICS, GSTDM and MPO models and to propose a consistent framework of SE data categories that improved the input data and allowed it to be transferrable and comparable across different models in the Georgia.

GDOT is responsible for maintaining and updating the travel demand models for all MPOs except Atlanta Region, within Georgia. The GSTDM model development team coordinated with the Georgia Institute of Technology study team on a research project sponsored by GDOT regarding GSTDM and MPO model integration . Part of the outcome of this study included recommendations on some of the GSTDM model input updates to improve the better integration between the GSTDM and the MPO models. The recommended updates include TAZs updates, network updates, and input network attributes updates.

2.3.6 Improvement to Detailed Model Documentation

The present report encapsulates an effort to improve the model documentation including additional information on data sources, data processing, and model validation performance.

3. HIGHWAY NETWORK

The highway network is the backbone of the GSTDM. It serves as the basic infrastructure that is utilized to develop travel demand and patterns. The network was originally developed primarily using the National Highway Planning Network (NHPN) along with GDOT's Road Characteristic (RC) file in the 2010/2040 GSTDM model.

The 2015/2050 input network for the GSTDM continued using the 2010/2040 input network extent. It covers the entire lower 48 states. The extent of the network helps to ensure a reasonable capture of the interstate travel that can be critical along some major gateway corridors. This is particularly important for measuring the major freight flows crossing the state line where truck travel can be problematic in congestion buildup and safety for highway travel. The primary focus of the model is to study the travel within Georgia and to some extent its immediate neighboring states.

The level of roadway detail and zonal geography is more detailed for the state of Georgia and the surrounding states. Outside Georgia and the five surrounding southeastern states, the roadway network is kept at the Interstate highway system level. This is because the GSTDM is designed to primarily assess the travel patterns within the state of Georgia and details in the roadway network are less important outside Georgia. On the other hand, the closer a particular region is to Georgia, the more important the details in the roadway network are for the assessment of cross-border travel patterns. Consequently, a four (4)-layered system for the network was created in the previous model versions as listed below depending on the distance from Georgia. The layered system was designed in a way so that details in the highway network diminish as it expands outward from the state of Georgia to the rest of the country.

The layer system was defined as follows.

- Georgia study area region (all 159 Georgia counties)
- A buffer region (including the adjacent portions of the five (5) southeastern states of Alabama, Florida, North Carolina, South Carolina, and Tennessee)
- The rest of the adjacent five (5) southeastern states
- Outlying states (the rest of the 42 states plus the District of Columbia)

The 2015 updated highway network continued using on the layer system. The following section summarizes the statistics of the key inputs from the updated GSTDM network.

3.1 FUNCTIONAL CLASSIFICATION

The 2010/2040 GSTDM includes a functional classification system categorized by rural and urban area types. According to FHWA's guidance, Highway Functional Classification Concepts, Criteria and Procedures 2013 Edition[4], all functional classifications now exist without distinction between urban and rural area types. Revised functional classification definitions include the following categories, as shown in Table 3-1.

[4] https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/

Table 3-1: Functional Classification Categories

FC2015	Description
1	Interstate
2	Freeway or Expressway
3	Principal Arterial
4	Minor Arterial
5	Major Collector
6	Minor Collector
7	Local

The functional classifications in GSTDM's highway network were reviewed and updated using GDOT's 2015 Roadway Characteristics (RC) dataset. The functional classifications included in the network by the different regions are listed in Table 3-2. The 2015 updated highway network consists of all roadways functionally classified as minor arterial and above. A limited number of collectors and local roads are included in the network within Georgia only to provide necessary connectivity in regions with little highway system. For the buffer region between Georgia and the outlying states, the network includes the appropriate level of detail required as outlined in Table 3-2. Outside the southeastern states, the network only represents the interstate freeway system because it has minimal impact on the travel within and immediately surrounding Georgia.

Table 3-2: Functional Classifications Included in Network Regions

Network Region	Interstate	Principal Arterials	Minor Arterials	Collectors/Local Roads (partial)
Georgia	✓	✓	✓	✓
Buffer Region	✓	✓	✓	
Rest of Adjacent States	✓	✓		
Rest of Nation	✓			

Figure 3-1 represents the extents and functional classifications of the updated 2015 GSTDM network. The total roadway mileage included in each network region is presented in Table 3-3. The base year network includes over 80,000 miles of roadway with 27 percent of the roadways located in the Georgia.

Figure 3-1: Base Year Highway Network by Functional Classification

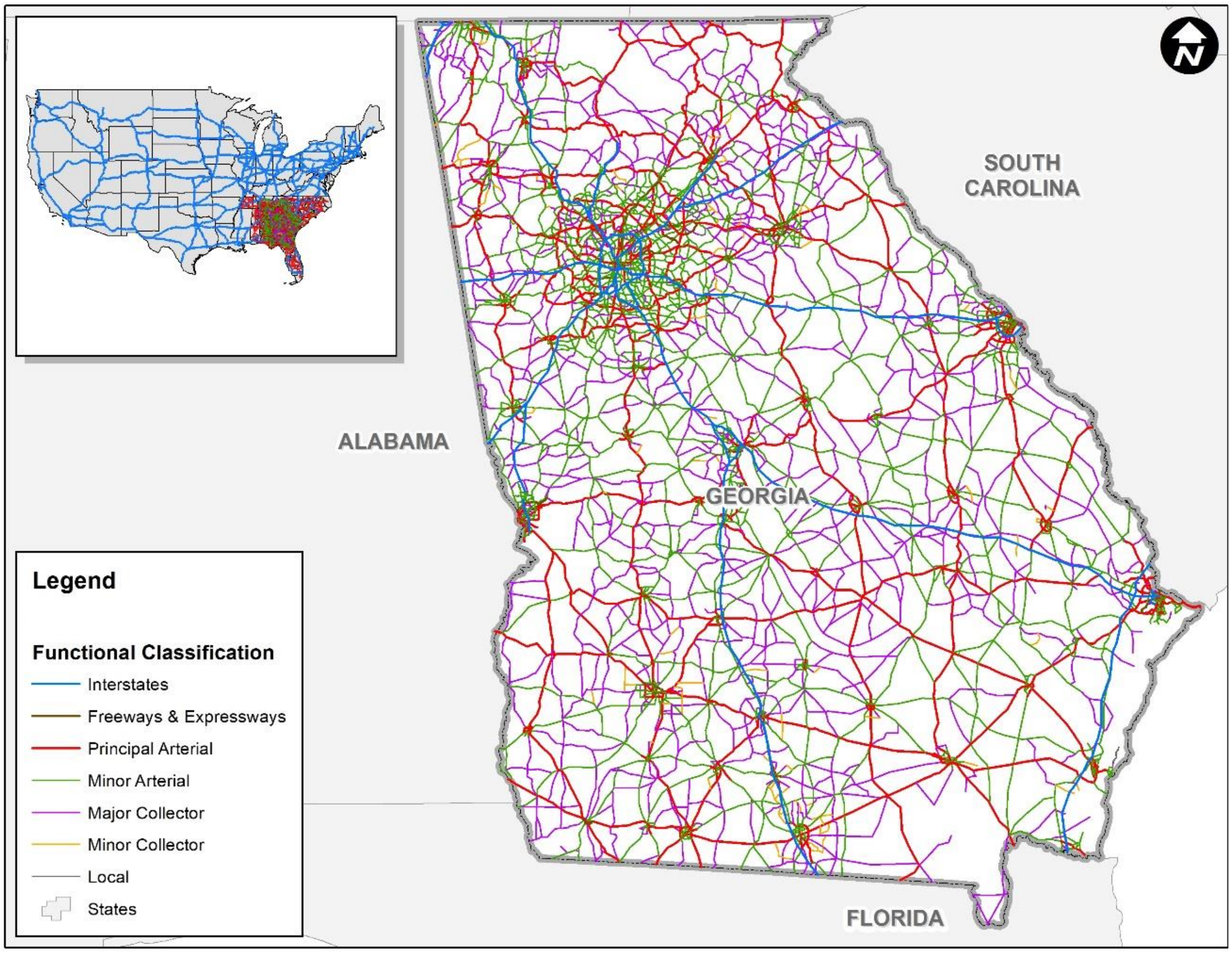


Table 3-3: GSTDM Network Mileage by Region

Network Region	Mileage	% of Total
Georgia	23,126	27%
Buffer region	7,825	9%
Rest of Adjacent States	18,356	22%
Rest of Nation	35,673	42%
Total	84,980	100%

With such a large-scale network, it is important to ensure that the network reasonably represents the existing roadway system. To assist with this effort, the network link distances were summarized by functional classification and compared with the roadway mileages reported in GDOT Mileage by Route and Road System Reports 455[5] (hereinafter referred as "GDOT 445 report"). Table 3-4 lists the comparison of the results on centerline miles basis. The comparison is consistent with the structure of the network layout. The difference in mileage for the roadway classifications below the minor arterial is significant because not all collectors are included and the roadway system within MPO areas is less in detail. The small differences for higher facilities are likely due to the skeleton of links and nodes in the network and the true distance along the roadways. As part of the 2015 update, additional minor arterials were added to the network increasing the minor arterial coverage from 7,498 centerline miles in the 2010/2040 model to 9,042 centerline miles in the 2015/2050 model. Network coverage includes nearly 100 percent of interstates and principal arterials.

Table 3-4: Comparison of Network Centerline Mileage with GDOT 445 Report

Highway Facility	GDOT 445 Report	Model	% Diff
Interstate and Freeway	1,423	1,407	-1%
Principal Arterial	4,795	4,737	-1%
Minor Arterial	9,524	9,042	-5%
Collector	22,901	7,876	-66%

Functional classifications are the direct input for the GSTDM in combination with the area type (explained in Section 3.3), and they provide the framework for organizing the network into sub-groups so that free-flow speeds and capacities can be assigned. The functional classification is used to calculate the link capacity and speeds, as well as adjustments to the travel time. The updated functional classification is represented as FC2015 in the network attributes. The original functional classification (Fclass) in the 2010/2040 GSTDM is still being used in model processes. The relationship between the earlier category and the latest category is shown in Table 3-5.

[5] http://www.dot.ga.gov/DriveSmart/Data/Documents/400%20Series/445/DPP445_2015.pdf

Table 3-5: Relationship between Previous and New Functional Class

Previous (Fclass)		New (FC2015)	
1	Rural Interstate	**1**	Interstate
2	Rural Principal Arterial	**3**	Principal Arterial
6	Rural Minor Arterial	**4**	Minor Arterial
7	Rural Major Collector	**5**	Major Collector
8	Rural Minor Collector	**6**	Minor Collector
9	Rural Local	**7**	Local
11	Urban Interstate	**1**	Interstate
12	Urban Freeway or Expressway	**2**	Freeway or Expressway
14	Urban Principal Arterial	**3**	Principal Arterial
16	Urban Minor Arterial	**4**	Minor Arterial
17	Urban Collector	**5**	Major Collector
19	Urban Local	**7**	Local

3.2 NUMBER OF LANES

In addition to the appropriate representation of the distribution of roads as discussed in the previous section, the number of lanes of the modeled roads need to resemble observed data. The number of lanes on each roadway link was examined and updated as appropriate to represent 2015 number of lanes. The primary data source used was GDOT's 2015 Roadway Characteristics (RC) dataset and the number of lanes were spot checked using Google Earth historic imagery to reflect the 2015 conditions. Table 3-6 contains the resultant comparison of the number of lane-miles in the model network and in the GDOT 445 report.

Table 3-6: Lane-Miles by Functional Classification

Functional Classification	GDOT	Model	% Diff
Interstate	7,794	7,679	-1%
Principal Arterial	16,599	16,019	-3%
Minor Arterial	21,933	20,316	-7%
Collector	46,344	15,993	-65%

3.3 AREA TYPE

Area type is used in the GSTDM to help determine capacity and free-flow speed for different facilities. Area type is commonly defined by the intensity of land use and human activities, which are measured by population and employment density. In the previous version of the GSTDM, 2010/2040 version, the existing area types are solely based on population density. Not only does this differ from common modeling practice, it may not represent the area correctly. For example, when an area has very few residents, it will be classified as a rural area, while in reality it could either be a rural area with little human activity or a busy employment center with little residential land use.

The previous version of the GSTDM consisted of the following three area types and definitions in terms of population density:

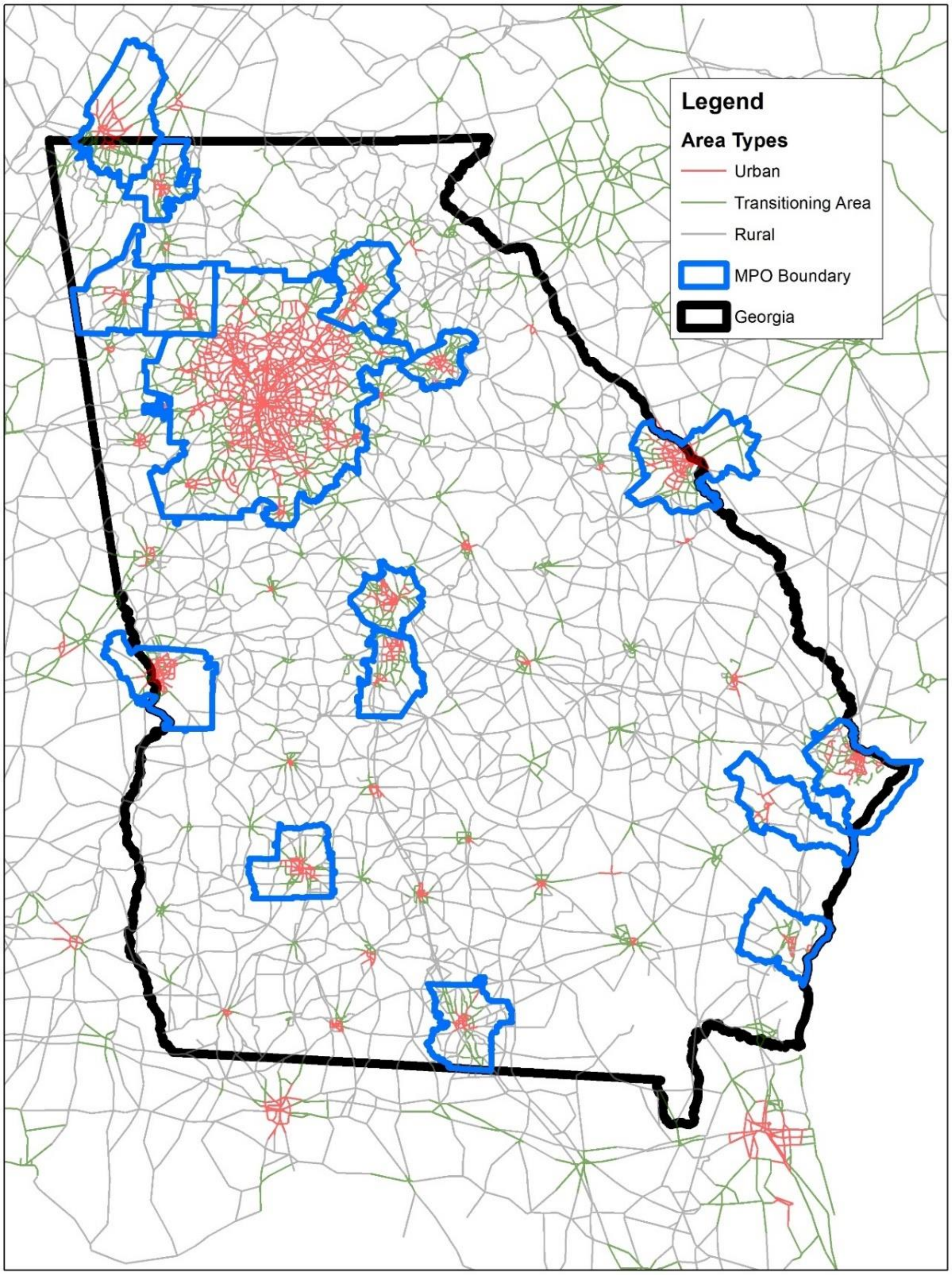
- MPO: > 1,000 persons/square mile
- Urban: 150-1,000 persons/square mile
- Rural: <= 150 persons/square mile

To refine the area type definition, the model development team refined area type definition using a population and employment density combined look up parameters. The refined area type definition is shown in Table 3-7 and is based on both the population and employment density. Figure 3-2 shows Area Type for the 2015 base year network links. MPO boundaries are included in the map as well to provide context.

Table 3-7: Area Type Lookup

Employment Density (Employees/sq. mile)	Population Density (persons/sq. mile)		
	<=150	150-1000	>1000
<=150	Rural	Transiting Area	Urban
150-1000	Rural	Transiting Area	Urban
>1000	Transiting Area	Urban	Urban

Figure 3-2: Area Type



3.4 ROADWAY CAPACITY AND SPEEDS

The roadway capacity and free flow speeds, are important factors when assigning traffic on the highway network. The GSTDM model stream uses daily capacities to determine the volume delay functions in the traffic assignment process. The daily capacities and free flow speeds were updated during the 2010 to 2015 base year model updates.

During the development of time-of-day post-processing assignment (see Chapter 9), the model development team also developed hourly capacities for highway input network. Various data sources were investigated to estimate the speeds and capacities of the roadway facilities. Major documentation and data sources, that were current at the time of GSTDM development, include:

- Florida Department of Transportation (FDOT) 2013 Quality/Level of Service Handbook[6];
- Highway Capacity Manual 2010 (HCM2010);
- NCHRP 427 - Extent of Highway Capacity Manual Use in Planning (2012); and
- NCHRP 599 - Default Values for Highway Capacity and Level of Service Analyses (2008).

The capacity and speed tables were developed using the Generalized Level of Service (LOS) Volume Tables[7] from the FDOT 2013 Quality/Level of Service Handbook. The capacity and speed tables in the Handbook were based on the definitions and methodology of the HCM2010 and are believed to be the most thoroughly researched and state-of-the-art Generalized Service Volume Tables in use nationwide.

FDOT Generalized Service Volume Tables present maximum service volumes or the highest numbers of vehicles for a given LOS. For the capacity development, the LOS D or LOS E service volumes from the daily tables and hourly directional tables were used to represent the daily capacity and the peak-hour capacity of the roadway, respectively. However, the roadway daily capacities far exceeds the daily volumes as shown in table 3-8, as all roadways are underutilized during the off-peak periods.

FDOT Generalized Service Volume Tables are used by appropriately applying the right area type and facility type designations and selecting the correct values from the tables. It should be understood that no single roadway has the exact values for all the roadway, traffic, control, and multimodal variables used in the Generalized Service Volume Tables. The tables must be applied with care to roadway facilities and in the determination of the LOS grade and capacities.

Following are the area types defined by the FDOT LOS Handbook:

- MPO/Urban areas - Urbanized areas are defined by the FHWA-approved boundary, which encompasses the entire Census Urbanized Area, as well as a surrounding geographic area as agreed upon by DOT, FHWA, and the MPO. The minimum population for an urbanized area is 50,000.

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[6] https://www.fdot.gov/planning/systems/documents/sm/default.shtm#los

[7] https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/content/planning/systems/programs/sm/los/pdfs/fdot_2012_generalized_service_volume_tables.pdf?sfvrsn=cf17ad0a_0

- Transitioning areas - Transitioning areas are fringe areas that exhibit characteristics between rural and urbanized/urban. Transitioning areas are intended to include areas that, based on their growth characteristics, are anticipated to become urbanized or urban in the next 20 years. These are areas with population over 5,000 and not in the urbanized Areas.
- Rural areas - Rural areas consist of two types:

    1. Rural undeveloped – Areas in which there is no or minimal population or development

    2. Rural developed – Cities and areas with other population less than 5,000 or areas along coastal roadways.

Generally, the cities or developed areas portion of the Generalized Service Volume Tables should be applied to areas with a population between 500 and 5,000 and not immediately adjacent to urbanized or transitioning areas.

The GSTDM has the following three area types, which are related to the area types defined in the FDOT LOS Handbook as follows:

- Urban – Same as MPO/Urban areas from FDOT LOS Handbook
- Transitional Areas – Same as Transitioning areas from FDOT LOS Handbook
- Rural – Same as Rural areas from FDOT LOS Handbook

The resultant speed and capacity tables for both daily capacity and hourly capacity by functional classification type and by area type are presented below. Table 3-8 shows daily capacity by facility type and Table 3-9 shows multilane factors for daily capacity. Table 3-10 and Table 3-11 show hourly capacity by facility type and multilane factors for hourly capacity, respectively. Table 3-12 shows free flow speeds by facility type.

Table 3-8: GSTDM per Lane Daily Capacity by Functional Classification

Functional Classification Type ID	Functional Classification Description	Previous Daily Capacity			Revised Daily Capacity		
		Urban	Transitioning Area	Rural	Urban	Transitioning Area	Rural
1	Interstate	19,125	17,275	15,750	19,880	17,930	15,400
2	Freeway/Expressway	19,125	17,275	15,750	18,480	17,450	15,200
3	Principal Arterial	8,450	8,150	11,150	8,640	8,190	12,000
4	Minor Arterial	7,750	7,650	7,450	7,890	7,180	7,100
5	Major Collector	6,300	6,150	7,450	7,580	7,000	6,500
6	Minor Collector	6,300	6,150	6,050	6,940	6,500	6,050
7	Local	6,300	6,150	6,050	6,300	6,000	5,500

Table 3-9: GSTDM Multilane Factors for Daily Capacity

Functional Classification Type ID	Functional Classification Description	Previous Factors			Revised Factors		
		Urban	Transitioning Area	Rural	Urban	Transitioning Area	Rural
1	Interstate	1.08	1.07	1.04	1.04	1.04	1.03
2	Freeway/Expressway	1.08	1.07	1.04	1.04	1.04	1.03
3	Principal Arterial	1.08	1.05	1.31	1.08	1.08	1.01
4	Minor Arterial	1.05	1.05	1.05	1.02	1.06	1.02
5	Major Collector	1.05	1.05	1.05	1.01	1.01	1.01
6	Minor Collector	1.05	1.05	1.05	1.01	1.01	1.01
7	Local	1.05	1.05	1.05	1.01	1.01	1.01

Table 3-10: GSTDM per Lane Hourly Capacity by Functional Classification

Functional Classification Type ID	Functional Classification Description	Peak-Hour Capacity		
		Urban	Transitioning Area	Rural
1	Interstate	1,970	1,790	1,750
2	Freeway/Expressway	1,680	1,630	1,600
3	Principal Arterial	860	830	1,200
4	Minor Arterial	830	760	750
5	Major Collector	810	770	700
6	Minor Collector	740	700	650
7	Local	660	630	600

Table 3-11: GSTDM Multilane Factors for Hourly Capacity

Functional Classification Type ID	Functional Classification Description	Revised Factors		
		MPO	Urban	Rural
1	Interstate	1.04	1.04	1.03
2	Freeway/Expressway	1.04	1.04	1.03
3	Principal Arterial	1.08	1.08	1.01
4	Minor Arterial	1.02	1.06	1.02
5	Major Collector	1.01	1.01	1.01
6	Minor Collector	1.01	1.01	1.01
7	Local	1.01	1.01	1.01

***Note**: Same factors as for Daily Capacity*

Table 3-12: GSTDM Free Flow Speed by Facility Type

Functional Classification Type ID	Functional Classification Description	Previous Speed (mph)			Revised Speed (mph)		
		MPO	Urban	Rural	MPO	Urban	Rural
1	Interstate	65	68	70	65	70	70
2	Freeway/Expressway	55	60	65	55	60	65
3	Principal Arterial	50	55	63	45	50	55
4	Minor Arterial	40	45	55	40	45	50
5	Major Collector	35	40	45	35	40	45
6	Minor Collector	30	35	40	30	35	40
7	Local	20	25	30	20	25	30

3.5 TRAFFIC COUNT LOCATIONS

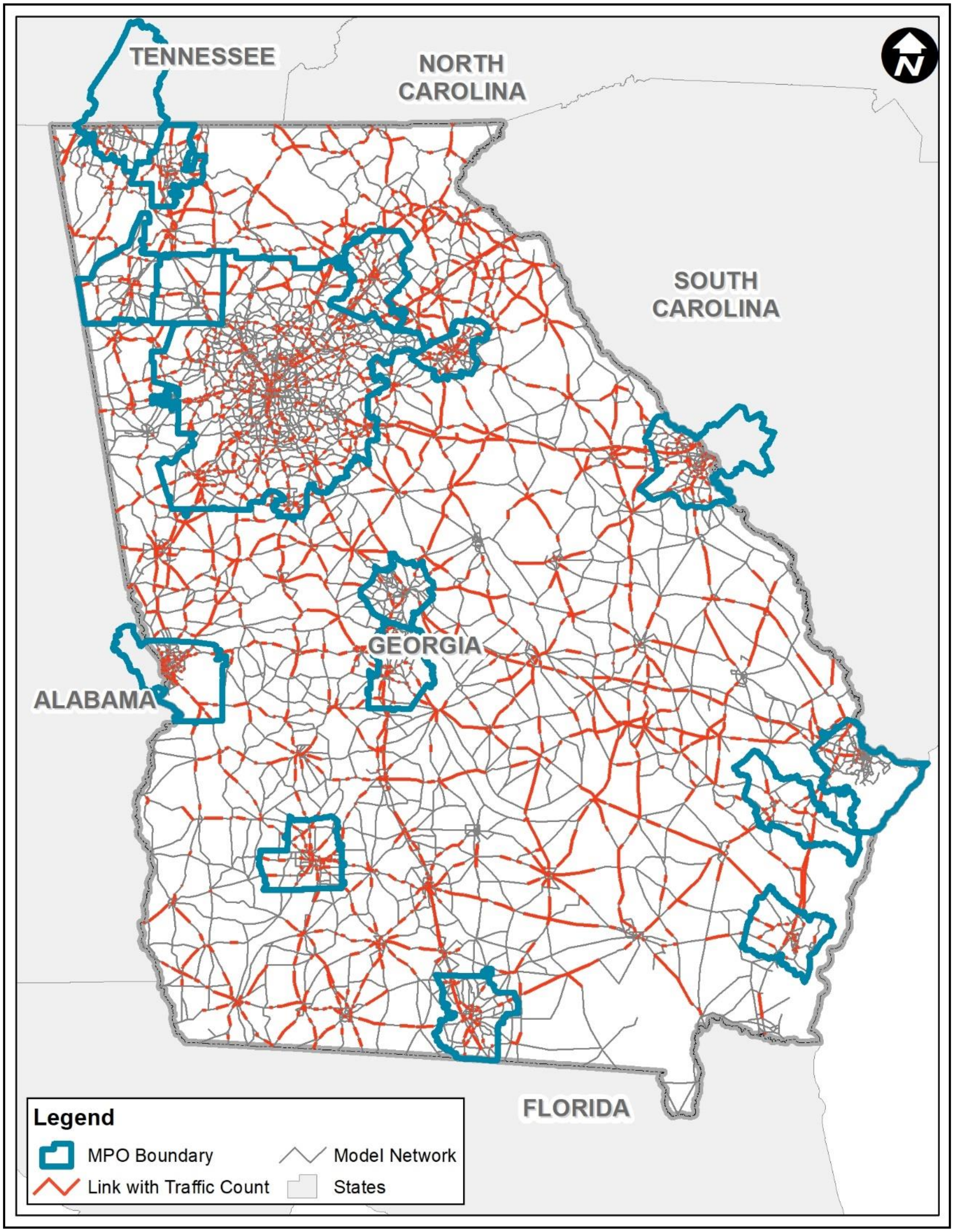
Traffic counts are primarily used for the validation of highway assignment during base year travel demand model development. Count data is used in link-level comparisons of modeled and observed volumes, for comparisons of volumes for selected groups of links such as screenline, cutlines, as well as system level comparison by functional classification.

GDOT's GeoCount data, now the Traffic Analysis and Data Application (TADA[8]), is GDOT's official traffic count system and was used as the primary traffic count data source for GSTDM development and application. GDOT conducts a regular program where traffic count data are gathered from sensors along highways and streets. From these data, estimates of the average number of vehicles that traveled each segment of road are calculated and GDOT periodically publishes these estimates. The previous GeoCount website, now the TADA website, included all the traffic counts with the Annual Average Daily Traffic (AADT) estimates.

The GeoCount data provided traffic counts at nearly 27,000 count stations. There are approximately 3,900 count stations coded in the Georgia area (see Figure 3-3). The reduced number of counts is due to the coverage level of the GSTDM network compared to statewide roadway network. It does not contain complete coverage of facilities with functional classification lower than minor arterial. Counts on roads that were not included in the network were excluded. In addition, counts less than 100 were omitted.

[8] https://gdottrafficdata.drakewell.com/publicmultinodemap.asp

Figure 3-3: Location of Traffic Counts



3.6 EXTERNAL STATIONS AND TRAFFIC

The GSTDM uses a seed matrix for external to external (E/E) trip tables. Due to lack of proper sources for E/E trips, a conservative approach was taken for external trip estimation. Average traffic growth was estimated for stations outside of Georgia which estimated to be close to 1 percent and applied to 2010/2040 GSTDM trip matrices. However, during validation it was found that this resulted in overestimation of trips and further adjustments were made that brought the EE seed matrix close to the 2010 matrix.

3.7 INPUT NETWORK ATTRIBUTES

Table 3-13 lists all the attributes in the current input highway network.

Table 3-13: Highway Network Attributes

Attribute Name	Description	Format
Distance	Link distance (in miles)	Number
Primary_Name	Primary road route sign	Text
Secondary_Name	Secondary road route sign	Text
Local Name	Local street name	Text
Fclass	Functional class – for use in the model only 1 - Rural Interstate 2 - Rural Principal Arterial 6 - Rural Minor Arterial 7 - Rural Major Collector 8 - Rural Minor Collector 9 - Rural Local 11 - Urban Interstate 12 - Urban Freeway or Expressway 14 - Urban Principal Arterial 16 - Urban Minor Arterial 17 - Urban Collector 19 -Urban Local 32 - Centroid Connector	Numeric
Lanes	Number of lanes	Numeric

Attribute Name	Description	Format
NHS	National Highway System - 2015 0 - Not on NHS 1 - Interstate 2 - NA 3 - Non-Interstate STRAHNET 4 - STRAHNET Connector 5 - NA 6 - NA 7 - Other NHS 8 - Approved Intermodal Connector	Numeric
STRAHNET	Strategic Highway Network - 2015 0 - Not on STRAHNET 1 - STRAHNET Priority 1 Connector 2 - STRAHNET Priority 2 Connector 3 - Non-Interstate STRAHNET 4 - Interstate Urban 16ft Vertical Clearance Route 5 - Interstate - Non-designated Urban 16ft Vertical Clearance Route 6 - Interstate-all other	Numeric
County	County name	Text
Tc_Number	Traffic count station number	Text
MPO_Name	MPO name	Text
TMA	N/A (not used)	
Screenline	Screenline location 1 - Chattahoochee River S of Lake Lanier 2 - Oconee River 3 - Norfolk Southern RR S N/S 4 - Norfolk Southern RR N N/S 5 - CSX RR E/W 6 - Chattahoochee River N of Lake Lanier	Numeric

Attribute Name	Description	Format
FIPS	County Federal Information Processing Standard Publication (FIPS) code	Numeric
State Route	State route indicator 0 = not on State Route System 1 = on State Route System	Numeric
Ext_Station	State External Location 1 - State External Station 0 - Not a State External Station	Numeric
Ext_Direction	State External Location by Orientation 1 - Northern Boundary 2 - Eastern Boundary 3 - Southern Boundary 4 - Western Boundary	Numeric
MPO_Station	MPO External Station Ranges 10,000 - 10,999 - Albany 20,000 - 20,999 - Athens 30,000 - 39,999 - Atlanta 40,000 - 49,999 - Augusta 50,000 - 59,999 - Brunswick 60,000 - 69,999 - Columbus 70,000 - 79,999 - Dalton 80,000 - 89,999 - Hinesville 90,000 - 99,999 - Macon 100,000 - 109,999 - Rome 110,000 - 119,999 - Savannah 120,000 - 129,999 - Valdosta 130,000 - 139,999 - Warner Robins 140,000 – 149,999 Cartersville 150,000 – 159,999 Gainesville	Numeric
Pctoll	Passenger toll section	Numeric
Trktoll	Truck toll section	Numeric

Attribute Name	Description	Format
Use	Truck only lane indicator	Numeric
AADT2015	2015 traffic counts	Numeric
TRK2015	2015 truck traffic counts	Numeric
REMI_2016	REMI regions (1 - 42) Refer to Section 3.5.1 for a map and list of the districts	Numeric
FC2015	2015 HPMS Functional Classification 1 Interstate 2 Freeway or Expressway 3 Principal Arterial 4 Minor Arterial 5 Major Collector 6 Minor Collector 7 Local	Numeric
MPO_Code	1 - Atlanta 2 - Gainesville 3 - Cartersville 4 - Rome 5 - Athens 6 - Dalton 7 - Augusta 8 - Macon 9 - Columbus 10 - Warner Robins 11 - Albany 12 - Hinesville 13 - Savannah 14 - Brunswick 15 - Valdosta 16 - Chattanooga/Catoosa	Numeric

3.8 ADDITIONAL REVISIONS AND UPDATES

Changes implemented to update the base year network from 2010 to 2015 are provided in the following sections.

3.8.1 Missing Interchanges and Links

The 2010/2040 GSTDM input network omitted some interchanges along the interstate system within Georgia. The interchanges along the interstate system in Georgia were updated and included in the 2015 input network. Major roadway projects that were completed by 2015 were also updated in the input network. GDOT project lists and Google Earth were used as the data source.

3.8.2 Link Distance

Link distances in the 2010/2040 input network were found to have errors at multiple locations. This usually occurs when the link distance is manually overwritten. The 2015 distances were recalculated using Cube's built-in feature and compared with the coded distances. When the percentage difference was large (more than 10 percent), those distances were double checked and revised as needed.

3.8.3 Links Based on MPO and County Boundaries

There are 16 MPOs within Georgia. Updated MPO jurisdiction boundaries were utilized to reflect the planning area for each MPO. The model development team reviewed highway links and updated with the MPO names in case they fall in an MPO region. This information was useful in understanding and facilitating the better integration of the GSTDM with MPO models (see Section 2.2). In addition, the county information was also identified and updated on highway links.

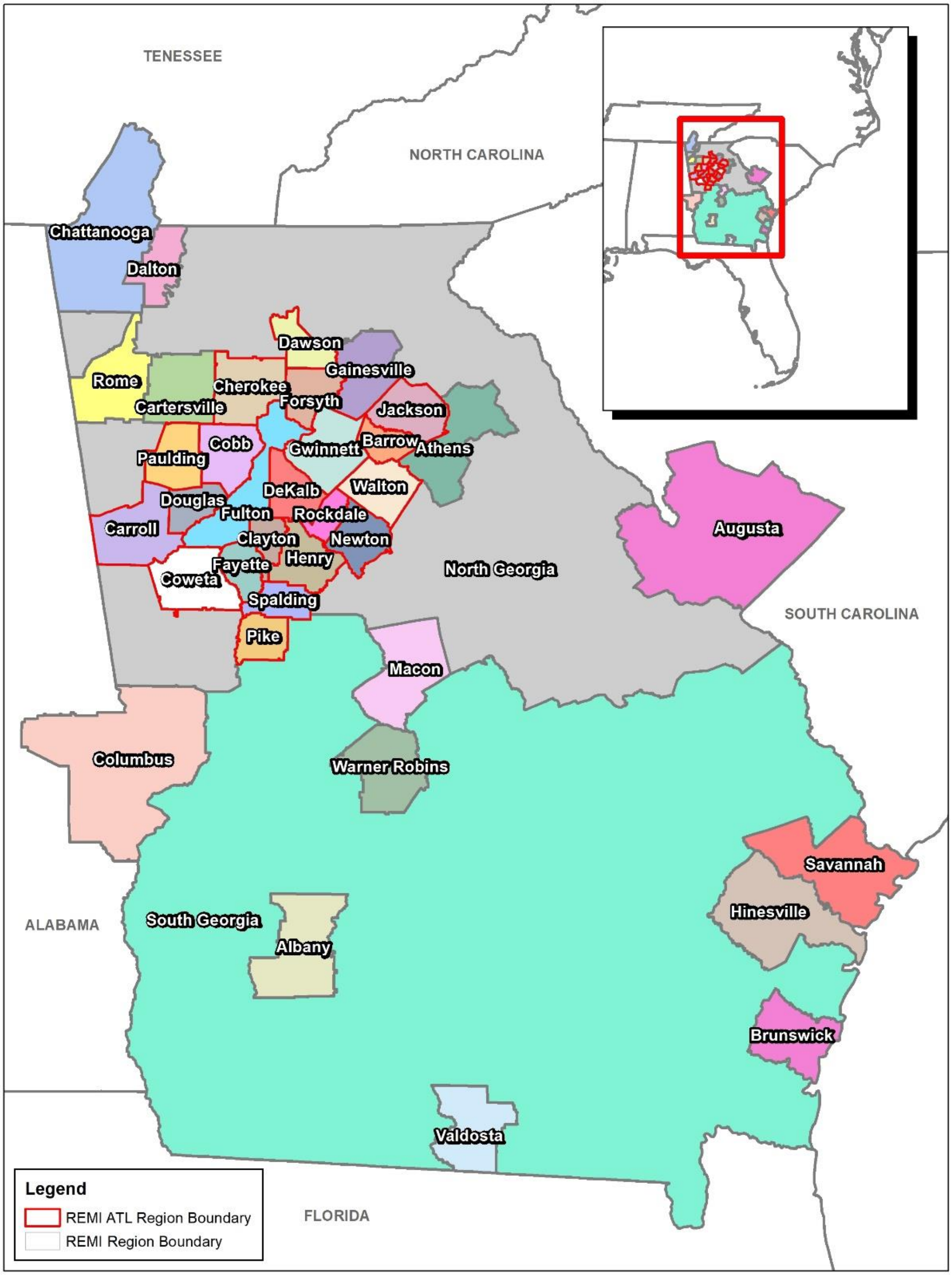
3.8.4 Links Based on REMI Regions

The GSTDM model includes Regional Economic Models, Inc. (REMI) model region information in the input network. This could assist to obtain/summarize model outputs with REMI regions and conduct further analysis with REMI model. The REMI model provides historical economic and demographic information and forecast f for 43 REMI regions listed in Table 3-14. Figure 3-4 display the REMI regions in Georgia. Employment by category and population forecast for each REMI district were considered in the development of the base year and future year socioeconomic data. Highway links within the REMI region boundaries were updated based on updated REMI regions in 2016.

Table 3-14: REMI Regions

REMI	NAME	REMI	NAME
1	Albany	**23**	DeKalb-ATL
2	Athens	**24**	Douglas-ATL
3	Augusta	**25**	Fayette-ATL
4	Brunswick	**26**	Forsyth-ATL
5	Cartersville	**27**	Fulton-ATL
6	Chattanooga	**28**	Gwinnett-ATL
7	Columbus	**29**	Henry-ATL
8	Dalton	**30**	Jackson-ATL
9	Gainesville	**31**	Newton-ATL
10	Hinesville	**32**	Paulding-ATL
11	Macon	**33**	Pike-ATL
12	Rome	**34**	Rockdale-ATL
13	Savannah	**35**	Spalding-ATL
14	Valdosta	**36**	Walton-ATL
15	Warner Robins	**37**	North Georgia
16	Barrow-ATL	**38**	South Georgia
17	Carroll-ATL	**39**	Alabama
18	Cherokee-ATL	**40**	Florida
19	Clayton-ATL	**41**	South Carolina
20	Cobb-ATL	**42**	Tennessee
21	Coweta-ATL	**43**	Rest of US
22	Dawson-ATL		

Figure 3-4: REMI Regions



4. TRAFFIC ANALYSIS ZONE SYSTEM

A traffic analysis zone (TAZ) is a geographical area that encompasses residential, social and economic activities. TAZS are origins and destinations of trips based on aggregated socioeconomic (SE) data which is used to estimate the trip generation (trip productions and attractions) for each zone. In the GSTDM there are 3,770 TAZs representing 48 states and the District of Columbia. Similar to the tiered network system, the TAZs are more numerous and smaller in size within Georgia to provide finer detail for analysis of travel within the state. The TAZs then progressively become larger and less detailed moving outward from the state. This is also to ensure the zone system and network are comparable in design. The 2015/2050 GSTDM maintains this TAZ tiered system with necessary updates.

The development and updates of the TAZ system for the GSTDM required the collection of the GIS geographic boundary files, Census data, and employment data. The major data sources used were U.S. Census data, Census TIGER files, Longitudinal Employer-Household Dynamics (LEHD), InfoGroup, Bureau of Economic Analysis (BEA), and Georgia Department of Labor (DOL). The boundaries of TAZs are updated to be consistent with the geographic boundaries of the Census data. The TAZ system includes not only the individual geographic locations of the TAZs but also contains the SE data associated with the zones. The SE data for each zone reflects the amount of activities that can produce trips to and from the zone.

4.1 DEVELOPMENT OF TAZ BOUNDARIES

TAZ boundaries are established using a combination of political and geographic boundaries in conjunction with roadways. The 2015 TIGER/LINE Shapefile is the primary GIS data source to updatethe TAZ boundaries. The Census data collected in developing the TAZ boundaries were:

- U.S. States
- U.S. Counties
- U.S. Census Tracts
- U.S. Census Blocks
- Water Boundaries
- Urban Area Boundaries
- TIGER/Line Street centerline

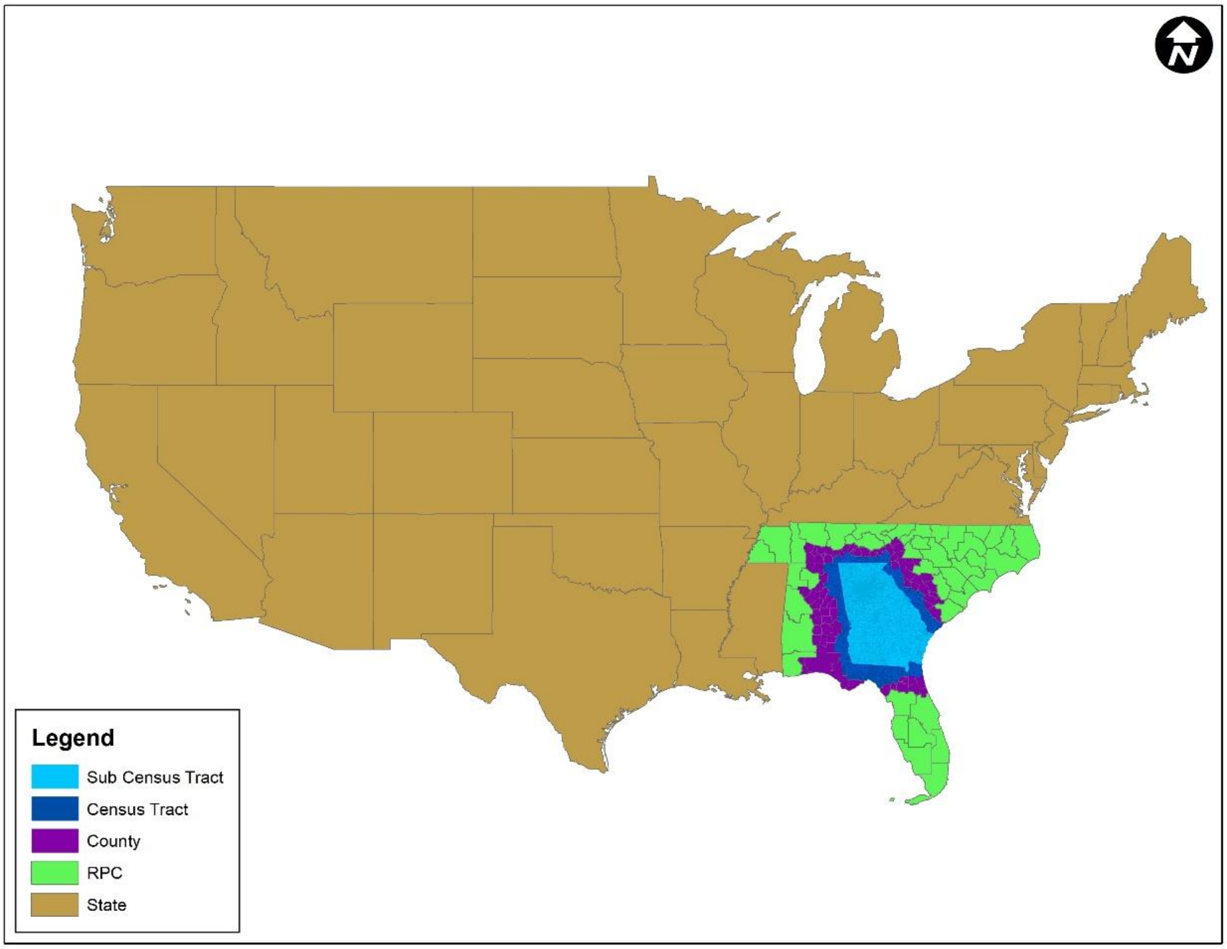
The water and urban area boundary files were used to review and update the natural boundaries for TAZs. The TIGER/Line street centerline file was used for any street delineation as additional reference data to the base input network and the GDOT RC centerline network file.

For the GSTDM 2015/2050 update, the input network maintained the original five (5) TAZ layer or strata system that was developed initially for the first version of GSTDM. The overall GSTDM TAZ layout structure is shown in Figure 4-1, which displays the extent for each of the TAZ geographic layers.

- State of Georgia: TAZs Census Tract size or smaller; Tracts aggregated in urbanized areas

- Adjacent Census Tracts: Buffer region in counties with Census Tracts immediately surrounding Georgia with zones comprised of Census Tracts
- Surrounding Counties: Counties outside the adjacent Census tract buffer region
- Surrounding Regional Planning Council (RPC) regions: Within adjacent states outside the surrounding county buffer
- Other States: Beyond the 5 states adjacent to Georgia

Figure 4-1: Map of GSTDM TAZs by Strata



In the current GSTDM 2015/2050 update, the TAZ system was revised using the 2015 Census data. The TAZ boundary consists of the model network centerline alignment as well as the roadway centerlines in the TIGER/Line file. The urban and water boundaries were also used to assist in defining the TAZ boundary delineation. TAZs are relatively smaller in size within and around the urbanized areas. The GSTDM will primarily be used for intercity travel forecasts. Intra-urban travel is difficult to be represented comprehensively at the statewide level, and the MPO models should be used for this purpose.

During the 2015/2050 GSTDM updates, a team from Georgia Institute of Technology was conducting a research on Integration of GSTDM and MPO models. They have reviewed the TAZ systems between the GSTDM and MPO models and recommended changes on the GSTDM and MPO models' TAZ system. The recommendations were reviewed and part of them were included in the 2015/2050 GSTDM updates.

As a result, there are 3,243 TAZs within the state of Georgia in the 2015/2050 GSTDM and 527 TAZs outside of Georgia. Table 4-1 presents the stratification of GSTDM TAZs. The highest zone number is 4027 in the model. There are dummy zones reserved for possible model expansion. Additional zones should replace the dummy zone number first. Georgia MPO boundaries are preserved within the TAZ system. Table 4-2 shows the TAZ numbering range and total number of TAZs by MPO represented in the model.

Table 4-1: TAZ Numbering by Region and Total Number

Region	From	To	# of Zones
Georgia	1	3,243	3,243
Adjacent Census Tract Buffer	3,501	3,864	364
Surrounding County Buffer	3,865	3,944	80
Surrounding RPC Buffer	3,945	3,984	40
Other States	3,985	4,027	43

Table 4-2: TAZ Numbering for MPOs

Region	From	To	# of Zones
Atlanta	1	926	926
Gainesville	927	1,048	122
Cartersville	1,049	1,078	30
Rome	1,079	1,078	0
Athens	1,132	1,229	98
Dalton	1,230	1,302	73
Augusta	1,303	1,387	85
Macon	1,388	1,461	74
Columbus	1,462	1,539	78
Warner Robins	1,540	1,599	60
Albany	1,600	1,648	49
Hinesville	1,649	1,692	44
Savannah	1,693	1,816	124
Brunswick	1,817	1,879	63
Valdosta	1,880	1,927	48
Chattanooga/Catoosa	1,928	1,974	47

4.2 SOCIOECONOMIC DATA DEVELOPMENT

Socioeconomic (SE) data, or land use data, provides the basis for generating the trips in the travel demand models. The GSTDM SE data set includes population, households and employment within Georgia by TAZs. Population and household data were updated for 2015 based on 2015 census data. The 2010/2040 GSTDM employment data categories were reviewed and reconciled into updated employment categories.

4.2.1 Population and Household Data

At the time 2015 SE data was developed, Census block level population and household data were not available from U.S. Census. Therefore, the following approach was used to develop the 2015 population and households for each TAZ in the GSTDM model.

U.S. Census data is the primary source for developing population and household data at the TAZ level. Because TAZ boundaries generally do not cross Census block boundaries, estimation of population and household data are usually aggregation processes from census blocks to TAZs. The U.S. Census does not provide block-level data for the years between each decennial Census. The smallest geographic area data for 2015 can be found from American Community Survey (ACS) 5-Year Estimates at Census tract level released in December 2016. Population and household estimates were developed for the 2015 TAZs based on 2010 Census block-level data, 2010 Census tract level data, and 2015 ACS 5-Year Census tract-level estimates and the following steps:

- Calculate the 2010 to 2015 growth rate for each Census tract based on the 2010 and 2015 Census tract data;
- Apply the growth rate to all 2010 Census block population and household data within each Census tract to get the 2015 Census block-level estimate.
- 2015 Census county-level population and household data was used as a reference and control to check the accuracy of the results.
- Assign/aggregate the calculated block level values to their respective TAZs.

The above method was applied to generate population and household data for TAZs within Georgia. Outside of Georgia, population and household data was generated by tiers. As outlined in the previous section, the tiers were zones comprised of Census tracts, counties, RPCs, and states. As those are larger Census boundaries than Census blocks, 2015 ACS 5-Year Estimates for the Census tracts, counties, RPCs and states were available and directly used to form a complete SE data set for the entire GSTDM model area.

4.2.2 Employment Data

One of the recommendations from the peer review was to facilitate integration of GSTDM with the Georgia MPO models. Therefore, a detailed review of the employment categories was performed for GSTDM and compared with the freight categories of North American Industry Classification System (NAICS) categories as well as the categories in MPO models. Following were the observations:

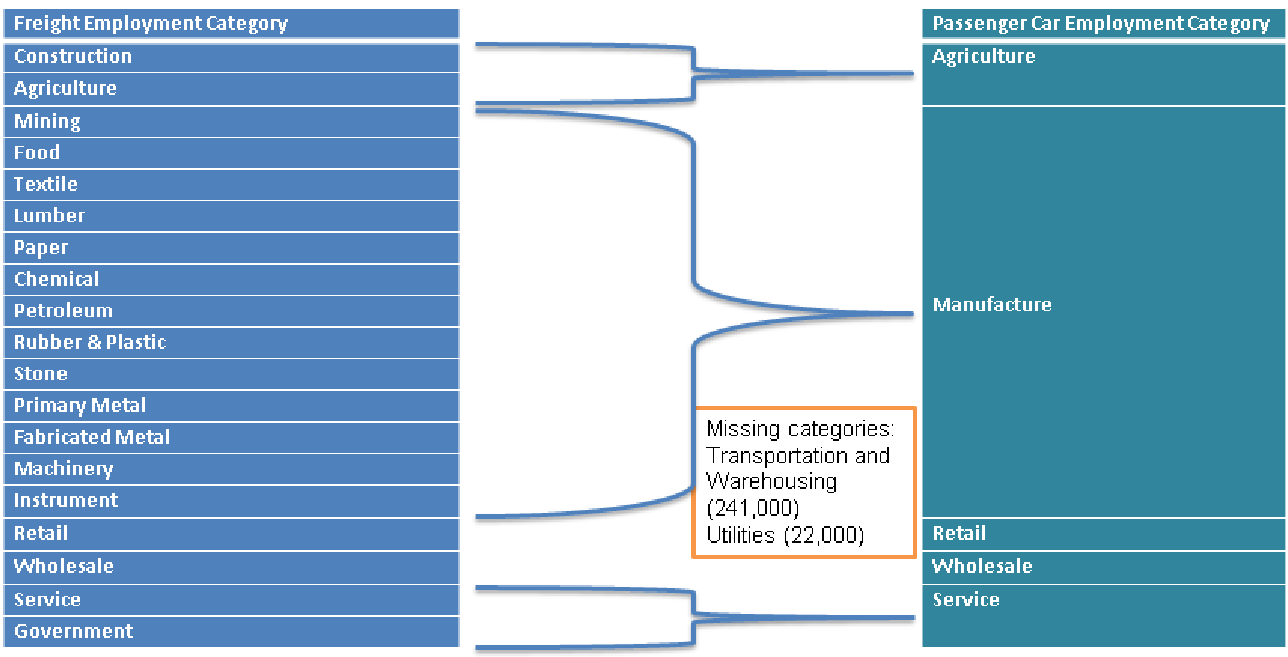
- Freight component employment categories did not include a few categories like Transportation and Warehousing, Utilities, and possibly more.
- Passenger Car component employment only includes what is included in the freight employment data.

Therefore, for the 2010 to 2015 update, the model development team decided to first reconcile the employment categories for consistency with NAICS and better integration with MPO models, and then update the employment data. The following sections describes the two steps in more details.

4.2.2.1 Employment Category Reconciliation

Figure 4-2 illustrates the employment categories used in the freight component and passenger car component of the 2010/2040 GSTDM, as well as the relationship between them. It indicates that the employment category data were generated from the freight employment data directly and some categories were omitted.

Figure 4-2: 2010/2040 GSTDM Employment Data Category



To correct the employment data inconsistencies noted above, the model development team established a SE data category reconciliation process. First, the team conducted a review of the employment categories in passenger components of seven different statewide travel demand models. The seven statewide models are from Michigan, Florida, Texas, Wisconsin, Iowa, South California and Indiana states. In general, the more detailed the network was, the more categories the model had. The major differences related in those models were how the service and manufacturing sectors were further divided. More employment categories can help enable more detailed trip purposes and time of day components, but the realization of such components also depends on the availability and quality of the data for model validation. The following summary shows how many employment categories were included in the statewide models for the seven states.

- < 5 Categories: Michigan (3), Florida (3-4), Texas (4), Wisconsin (4)
- 5 – 10 Categories: Iowa (7), South California (7), Georgia (5)
- > 10 Categories: Indiana (11)

The categories used in the Florida and Iowa models are chosen to be the primary references, as they had SE data structure similar to the GSTDM but with more appropriate relationship with the NAICS categories (See Table 4-3).

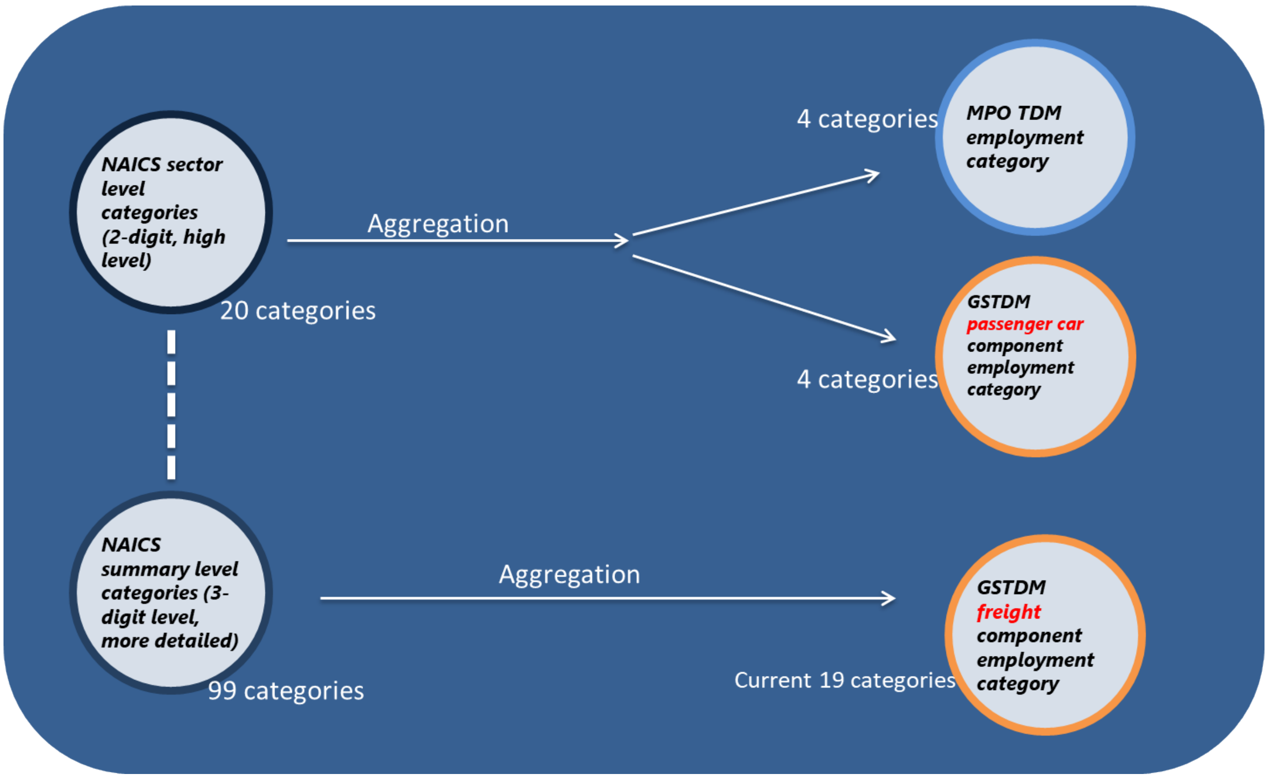
Table 4-3: Florida and Iowa Model Employment Categories and NAICS Categories

NAICS 2012 Codes		Florida	Iowa
N11	Agriculture, Forestry, Fishing and Hunting	Other Industrial	Agriculture, Mining & Construction
N21	Mining, Quarrying, and Oil and Gas Extraction		
N22	Utilities	Manufacturing Industrial	Transportation, Communications, Utilities, and Warehousing (TCUW)
N23	Construction	Other Industrial	Agriculture, Mining & Construction
N31-33	Manufacturing	Manufacturing Industrial	Manufacturing
N42	Wholesale Trade		Transportation, Communications, Utilities, and Warehousing (TCUW)
N44-45	Retail Trade	Retail/Commercial	Retail
N48-49	Transportation and Warehousing	Manufacturing Industrial	Transportation, Communications, Utilities, and Warehousing (TCUW)
N51	Information	Service	Financial, Information

NAICS 2012 Codes		Florida	Iowa
N52	Finance and Insurance		and Real Estate (FIRE)
N53	Real Estate and Rental and Leasing		
N54	Professional, Scientific, and Technical Services		
N55	Management of Companies and Enterprises		
N56	Administrative and Support and Waste Management and Remediation Services		Administrative & Educational
N61	Educational Services		
N62	Health Care and Social Assistance		Services
N71	Arts, Entertainment, and Recreation		
N72	Accommodation and Food Services		
N81	Other Services (except Public Administration)		
N92	Public Administration		Administrative & Educational

Based on the discussion above, the 2012 peer review, and the existing structures in the GSTDM, the model development team proposed a SE framework for the GSTDM update as shown in Figure 4-3. The GSTDM freight component employment category should be developed from the 99 NAICS summary level categories directly, depending on the correlation with commodity flows. GSTDM passenger car component employment category should be aggregated from the 20 NAICS sector level categories. It is recommended to have four categories for the GSTDM. Considering the integration between GSTDM and MPO travel demand models, developed by GDOT as well, the four categories are also recommended to use in the MPO travel demand models[9].

Figure 4-3: Framework for Employment Data Categories Development



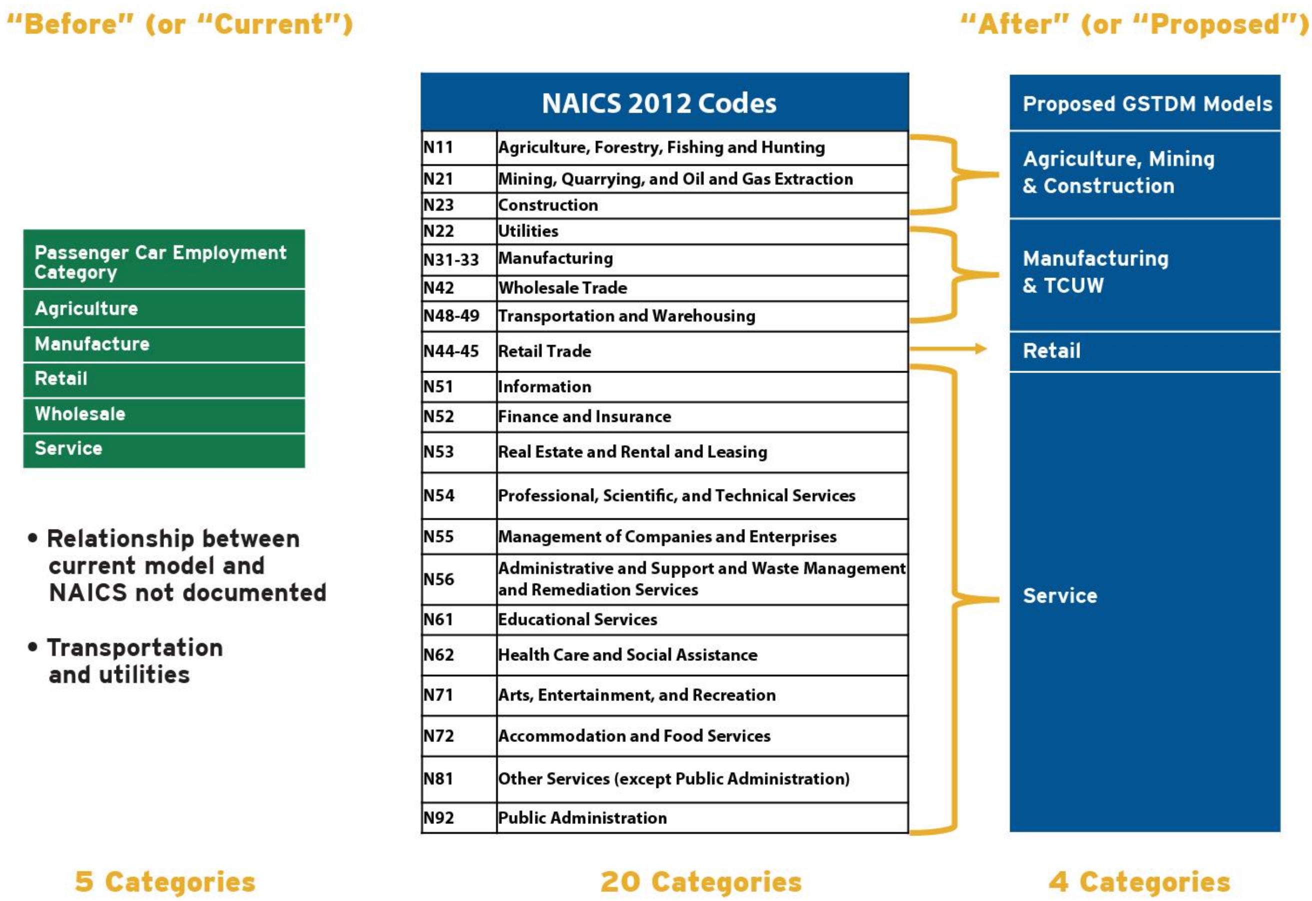
The four categories proposed for the passenger model employment data input are:

- Agriculture, Mining, and Construction;
- Manufacturing and Transportation, Communications, Utilities, and Warehousing (TCUW);
- Retail; and
- Service.

The detailed relationship with NAICS categories is illustrated in Figure 4-4.

[9] *At the time of GSTDM updates, the model development team created a SE data development guideline and provided to all MPOs to assist the development and updates of 2015 SE data. The guideline includes consistent methodology for developing TAZ level population, household and employment data for MPO travel demand models. The guideline can be found here:* *http://www.dot.ga.gov/InvestSmart/Documents/Travel%20Demand%20Model/SE_Development_Guildelines.pdf*

Figure 4-4: Proposed GSTDM Passenger Car Component Employment Data Categories



See Chapter 5 for additional information on the final freight employment categories.

4.2.2.2 Employment Data Update

Once the employment categories were established, the employment data was developed using the new categories and various data sources. As part of the GSTDM updates, GDOT purchased 2015 InfoGroup employment data which provided a unique source of geographically detailed employment data by category. The model development team aggregated the dataset to TAZs level by employment types.

2015 employment data from Department of Labor (DOL) was used as control totals to ensure the county-level total employment from InfoGroup data are in a reasonable range. Additional data sources were used for comparison of the estimated employment data, including:

- Atlanta Regional Commission's (ARC) employment forecasts used in its activity-based model – This was used to compare the employment forecast within the 20-county Atlanta region;
- REMI – Employment by category forecast for each REMI Region was used as a reference in the development of the base year socioeconomic data; and,
- Longitudinal Employer-Household Dynamics OnTheMap Data – The OnTheMap data set provides locations and number of employees, which were used as a reference during reviewing and confirming the accuracy of InfoGroup data.

Table 4-4 lists the TAZ employment data fields input in the model. The first 20 categories are employment types for freight model trip generation and the last five categories with grey shades are for passenger model. Table 4-5 provides a summary of total population, household and employment data used in the 2015 GSTDM. Refer to Figure 4-1 for a map of the five regions included in the table.

Table 4-4: Employment Data Fields

Category	Description
AGRI	Agriculture
MING	Mining
FOOD	Food Processing
TEXT	Textiles
LUMB	Lumber
PAPR	Paper Manufacturing
CHEM	Chemical Processing
PETR	Petroleum
RUBB	Rubber
STON	Stone
PMTL	Primary Metal
FMTL	Finished Metal
MECH	Machinery Manufacturing
INST	Instruments
CNST	Construction
RETL	Retail

Category	Description
WSLE	Wholesale
SERV	Service
GOVT	Government
REST	Other employment types
DOT_AMC	Agricultural, Mechanical, Construction
DOT_MTCUW	Manufacturing & Transportation, Communications, Utilities, and Warehousing
DOT_RETL	Retail
DOT_SERV	Service
DOT_TOTL	Total Employment

Table 4-5: GSTDM 2015 SE Data Total Summary

Region	From TAZ #	To TAZ #	# of TAZs	Total Population	Total Household	Total Employment
Georgia	1	3,243	3,243	10,006,691	3,574,362	4,019,280
Outside of Georgia – Census Tract Buffer	3,501	3,864	364	3,814,609	1,451,516	1,558,317
Outside of Georgia – County Buffer	3,865	3,944	80	7,249,610	2,765,995	2,911,418
Outside of Georgia – RPC Buffer	3,945	3,984	40	34,534,697	13,026,539	13,816,642
Outside of Georgia – Other States	3,985	4,027	43	258,769,738	95,406,352	112,135,900

5. FREIGHT MODEL

The GSTDM includes two major components, a freight and a passenger model. Each model performs the modeling steps independently except during the traffic assignment where the freight trucks, non-freight trucks and passenger vehicles are combined to reflect the total highway traffic conditions. This chapter describes the freight model component in the GSTDM.

There are several modes used in the transportation of freight. The majority of these modes include highways, railroads, pipelines, and waterways. Within this framework, it is important to remember that freight movement is not restricted to just the state level. Rather, it has more of a regional and national structure. The commodity flow database TRANSEARCH, from Global Insight, was the basis for assessing commodity flows within and out of the state and was used as the survey data to estimate the freight model. The GSTDM mainly focuses on the commodity flows on the highway and rail systems that account for more than 75 percent and 22 percent of total commodity flows in Georgia, respectively. The potential interaction between the modes is important in evaluating the truck movement along the critical corridors of the interstate system. The model provides a toolkit that can evaluate the potential shift of commodity traffic between highway and rail. A description of the rail network variables is listed in Appendix E.

5.1 FREIGHT/TRUCK TRAVEL DATA DEVELOPMENT

The 2015 freight and truck travel data update used the TRANSEARCH database in the estimation of freight model equations and the external-to-external (E-E) freight trip tables. The most recent available TRANSEARCH data was for the year 2013.

TRANSEARCH is a freight database that is available commercially from Global Insight. TRANSEARCH utilizes a multitude of mode-specific data sources to create a picture of the nation's freight traffic flows on a market-to-market commodity basis. The national database, from which purchases of TRANSEARCH are developed, has U.S. counties as the primary flow unit, although TRANSEARCH can use proprietary data to provide a more disaggregated level of geography. Each record in the TRANSEARCH database represents the flow from an origin zone to a destination zone.

TRANSEARCH is created each year using the following:

- The Annual Survey of Manufacturers (ASM) to establish production levels by state and industry;
- The Surface Transportation Board (STB) Rail Waybill Sample to develop all market-to-market rail activity by industry;
- The U.S. Army Corps of Engineers Waterborne Commerce data to develop all market-to-market water activity by industry;
- The Federal Aviation Administration (FAA) Enplanement Statistics; and
- Airport-to-airport cargo volumes.

TRANSEARCH uses this listed information, in conjunction with information on commodity volumes moving by air from the Bureau of Transportation Statistics (BTS) Commodity Flow Survey (CFS), to create more detailed air flows. Then the rail, water, and air freight flow data deduced from the Bureau of Census ASM-based production data to establish preliminary levels of truck activity. The proprietary Motor Carrier Data Exchange Program provides information on actual market-to-market trucking industry movement activity. The Data Exchange Program includes carriers from both the private and for-hire segments of the industry and both the truckload (TL) and less than truckload (LTL) sectors. The truckload sample covers about 6 percent of the market, and TRANSEARCH's LTL sample is about 40 percent. In total, information is received on over 75 million individual truck shipments. By way of comparison, the government's CFS covers about 12 million shipments, spread across all modes; and the Rail Waybill's sample rate is about 2.5 percent of all rail freight moves.

TRANSEARCH's county-to-county market detail is developed through the use of Global Insight's Motor Carrier Data Exchange inputs and Freight Locator database of shipping establishments. The Freight Locator database provides information about the specific location of manufacturing facilities, along with measures of facility size (both in terms of employment and annual sales), and a description of the products produced. This information is aggregated to the county level and used in allocating production among counties.

Much of the Data Exchange inputs from the trucking industry are provided by ZIP code. The ZIP code information is translated to counties and used to further refine production patterns. A compilation of county-to-county flows and a summary of terminating freight activity are used to develop destination assignments.

TRANSEARCH freight traffic flow data has limitations with respect to trucks:

- Traffic movements originating in warehouses, distribution centers, drayage movements of intermodal rail, or air freight are shown as STCC 5010. By definition, these are truck movements. Movements to warehousing and distribution centers may be by other STCC codes and by any mode. Details on the types of items being moved are not available.
- The inland or surface movements of import and export traffic volumes to locations outside of North America are included in the data. However, the flow patterns of this freight are based on the movement patterns of domestically sourced goods in the same market areas and are not the actual movements of the import/export freight.

Freight carried by trucks, based on the definitions used by the principal agencies collecting data, also typically excludes shipments to or from retail (excluding mail order and warehousing), offices, service establishments, and residences. These local freight or goods deliveries are significantly different from those freight shipments that are included in terms of the distances traveled, type of trucks used, times of movement, and routing of the shipment, but their exclusion does not detract from the larger freight-related issues.

5.2 FREIGHT MODEL ZONES AND NETWORKS

The TAZ structure for freight zones in the core GSTDM region is the same as those used in the passenger model. The highway network for the freight model is identical to the highway network that is used in the passenger model for the geographic area covered by the passenger model. Beyond this geographic area, highway links were added that represent the major National Highway System (NHS) roads in the United States. The purpose of the highway links outside Georgia is to provide connectivity to the TAZs in Georgia and the surrounding buffer regions.

5.3 COMMODITY GENERATION

5.3.1 Commodity Groups

The trip generation model produces the zonal commodity productions and attractions. This is similar to the trip production and attraction models in the conventional four-step passenger model. It creates two trip ends for each pair of origin-destination (O-D) flow. Rather than passenger trips, commodity flows are generated in the freight model. The freight trip generation model was estimated using the O-D flow by commodity type in the TRANSEARCH database.

There are 761 commodities identified by the Standard Transportation Commodity Code (STCC) code in the database. The commodity groups (CG) on which trip generation models are applied in the existing GSTDM are shown in Table 5-1. Because the explanatory variables are tied to these CGs, there was limited testing of modifications to these CGs. If new explanatory data are subsequently obtained, then an examination that might result in different CGs is recommended. The 2010/2040 model included 16 CGs. As was done for the most recent effort using 2013 TRANSEARCH, commodity generation regression models were investigated for CGs 17 and 18.

Table 5-1: GSTDM Commodity Groups (CG)

Number	Name	Abbreviation
1	Agriculture products	AGRI
2	Non-metallic mining	MING
3	Food and tobacco products	FOOD
4	Textile and apparel products	TEXT
5	Lumber, wood, and furniture products	LUMB
6	Paper and printing products	PAPR
7	Chemical products	CHEM
8	Petroleum and coal products	PETR
9	Rubber, plastic, and leather products	RUBB
10	Clay, stone, glass, and concrete products	STON
11	Primary metal products	PMTL
12	Fabricated metal products	FMTL
13	Machinery and transportation equipment	MACH
14	Instruments and miscellaneous manufacturing products	INST
15	Waste and scrap materials	WSTE
16	Mail, freight forward, and miscellaneous freight shipments	MAIL

Number	Name	Abbreviation
17	Waste hazardous substances and hazardous materials	HMAT
18	Bulk movement, secondary, intermodal, and warehouse traffic	SECN

5.3.2 Explanatory Data

The socioeconomic employment data for freight were derived from Infogroup 2015 data for each of the TAZs in the model. The freight model uses 19 categories as outlined in Table 5-2. These categories are more detailed than the aggregate employment available in the passenger model, which are categorized as AMC, MTCUW, SERV, and RETL corresponding to agriculture, manufacturing, service, and retail employment respectively. One of the advantages of the InfoGroup data is the availability of NAICS employment at three-digit levels, which can be directly aggregated to the associated commodity groups just described. These were directly aggregated at the TAZ geographic level using GIS processing and assembled into the 2015 base year SE data.

For the future scenario, the SE data were developed based on the passenger model employment categories used as control totals. A lookup table was created between the passenger model and freight model employment categories. Once the lookup table was developed, the base year freight employment values were factored up to 2050 by the growth in the respective passenger model employment category control total proportions. The resulting employment database was used to estimate the relationships of freight trip generation against TRANSEARCH 2013 reported freight flows. Table 5-2 shows the assumed relationship between the freight and passenger model categories.

Table 5-2: Correspondence of Freight and Passenger Employment

Freight Employment Category	Full Description	Passenger Model SE Attribute
AGRI	Agriculture	DOT_AMC
MING	Mining	DOT_MTCUW
FOOD	Food Processing	DOT_MTCUW
TEXT	Textile	DOT_MTCUW
LUMB	Lumber	DOT_AMC
PAPR	Paper Manufacturing	DOT_MTCUW
CHEM	Chemical Processing	DOT_MTCUW
PETR	Petroleum	DOT_MTCUW

Freight Employment Category	Full Description	Passenger Model SE Attribute
RUBB	Rubber	DOT_MTCUW
STON	Stone	DOT_MTCUW
PMTL	Primary Metal	DOT_MTCUW
FMTL	Finished Metal	DOT_MTCUW
MECH	Machinery Manufacturing	DOT_MTCUW
INST	Instruments	DOT_MTCUW
CNST	Construction	DOT_MTCUW
RETL	Retail	DOT_RETL
WSLE	Wholesale	DOT_RETL
SERV	Service	DOT_SERV
GOVT	Government	DOT_TOTL

5.3.3 Special Consideration for Ocean and Inland Ports

Special consideration was undertaken during the future year SE data development of the impact of proposed expansions to the Savannah ocean container ports to handle additional volumes. Savannah currently has two main container port areas including the Garden City Terminal and the Ocean Terminal that lie to the northwest of downtown Savannah. It was announced that these facilities will be expanded to accommodate additional TEUs (twenty-foot equivalent units). Additionally, plans have been announced for the development of a new greenfield port across and downriver in South Carolina called the Jasper Ocean Terminal. All these terminals have or are proposed to have excellent rail connections to the national network.

The model development team conducted a review of various studies, including the 2017 Jasper Terminal Report to determine the proper assumptions regarding number of trucks, truck/rail mode share, etc., for these terminals. The basic methodology followed to accommodate the additional trucks was to identify the increase in expected number of TEUs and trucks passing the gates (found in the report and press release[10]) for the Garden City Terminal. The existing freight model SE and special generator data was assumed to be correct for Ocean Terminal. For Jasper, the estimated number of weekly trucks in the Jasper Terminal was taken from the Moffat report. Table 5-3 describes the assumed additional trucks used in the study and the conversion to tonnage for inclusion in the freight modeling structure.

[10] http://gaports.com/media/press-releases/artmid/3569/articleid/217/savannah%E2%80%99s-teu-count-grows-75-percent-in-2018

The additional trucks estimated at Garden City and new trucks at Jasper were converted to daily tonnages using the average payload for intermodal dray trips of 17 tons to allow for direct use by the special generator procedures within the freight model. For Jasper, an additional consideration is that some of the trips will be E-E with respect to Georgia given that the port is proposed to be located in South Carolina. To accommodate this, the base year E-E versus I-E proportion from the Garden City Terminal were determined and the same relationship assumed for Jasper in 2050. This share was then used to apportion the extra Jasper Terminal tonnages between I-E/E-I tonnage inputs and the E-E trip table. The extra 2050 E-E trip interchanges were then allocated amongst all other external zones using the same proportions as the base year Garden City Terminal trips to/from these zones.

Table 5-3: Savannah Port Forecast Year Adjustments

Terminal	Annual TEUs	Trucks
Garden City Terminal[1]	6,500,000	85,312
Garden City Terminal Adjusted (latest numbers) [2]	8,000,000	104,999
Extra Value in SpcGEN	1,500,000	19,687
Ocean Terminal		3,770
Jasper Ocean Terminal[3]		14,892

1. *Truck estimate from Jasper Terminal Report, October 2017*
2. *Estimated additional TEUs from press release*
3. *Truck estimate from Jasper Terminal Report*

In addition to the ocean ports, three inland ports are in operation and/or planning phases in Georgia. It was determined that the volumes in one of the ports located in central Georgia near Cordele were low enough that the existing model structure and SE data inputs are sufficient to accommodate the differences. The two larger inland ports located in northwest and northeast Georgia require special consideration. Based on press releases[11] and stated as assumptions in Table 5-4, the total number of trucks expected to be handled annually is 125,000.

This was converted to a tonnage value using the payload factor of 17 and an annual factor. Once the daily tonnages were calculated, the zones for the location of the terminals were identified and the special generator values were updated for the Intermodal CG 18. The intermodal values were also correspondingly reduced for the Garden City Terminal to reflect the shift of the day trip from the ocean port to the inland port.

[11] https://appalachianregionalport.com/news/2018/arp-now-open
http://gaports.com/media/press-releases/artmid/3569/articleid/210/georgia-announces-new-inland-terminal-location

Table 5-4: Inland Port Tonnages

Location	Zone	Annual (Tons)	Daily (Tons)
Hall County (Gainesville) *	976	1,275,000	4,322
Murray County (Appalachian Regional Port) **	1293	850,000	2,881
Total		2,125,000	7,203

** Estimated 75,000 trucks at full buildout*
*** Estimated 50,000 trucks at full buildout*

5.3.4 Commodity Freight Production Equations

As described earlier and similar to the previous freight trip development effort, only one new production equation was developed for each commodity group using the 2013 Georgia TRANSEARCH as the estimation dataset. Reported productions for all 159 counties in Georgia were used as observed dependent data and no observation was removed from the regression. Infogroup 2015 employment were used as the independent data. A series of commodity flow generation equations were estimated for the statewide freight demand. These equations were developed for the annual commodity flow productions from GSTDM TAZs for internal-external (I-E) and internal-internal (I-I) trips using linear regressions of TRANSEARCH data and GSTDM employment at the county level.[12] The equations were developed at the county level because that is the common unit of geography for which the commodity, population, and GSTDM employment data are available. The relationships established at the county level will be applied to the TAZ-level data within the model application following freight trip distribution and freight mode choice.

The initial selection of appropriate employment and population variables to generate commodity volumes was guided by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA) Input-Output (I/O) Tables. Those tables report the commodities made or used by various industries. The tables were sorted by commodity, by GSTDM industry, and by the principal industries that made the commodity. Employment totals in those industries were always included as the proposed independent variables to be tested for the production equations.

The GSTDM estimates the annual internal portion of I-E and I-I tonnage produced by each CG to each TAZ in Georgia (with the exception of special generators) based on the regression equations. The explanatory variables tested within the production regression models included various employment categories. The annual external portion of I-E tonnage by commodity group was identified from the TRANSEARCH database.

[12] *It is standard practice in transportation modeling for trip generation equations to be linear equations with a zero intercept. More complicated equations, such as nonlinear equations, would have been investigated if they were thought to have been a statistical improvement. This was not found to be the case.*

The production equations were fit to the TRANSEARCH observed annual tonnage for all of the 18 CGs. The correlation and dependence of each were then assessed. The production equations developed through a linear regression are shown in Table 5-5. The equations yield the annual tonnage for each GSTDM TAZ based on the total GSTDM employment type for that TAZ. For all CGs, the production equation is a linear function of the one variable listed. The production tonnage for the CGs is best explained by the total employment of all industries in that same county. No tonnages were reported for CG 17, HAZMAT, and coefficients could not be developed.

Table 5-5: Production Coefficients by Commodity Group

Code	CG Name	2013 I-E Tonnage	2013 Estimated	Variable Name(s)	Coeff	t-Stat	R^2
1	Agriculture products	13,975,882	13,067,169	AGRI	822	12	0.5
2	Non-metallic mining	52,046,987	24,579,013	MING	8,924	19	0.7
3	Food and tobacco products	18,969,177	16,411,364	FOOD	300	22	0.8
4	Textile and apparel products	3,128,307	2,454,928	TEXT	47	24	0.8
5	Lumber, wood, and furniture products	18,778,723	6,488,991	LUMB	161	5	0.2
6	Paper and printing products	10,447,057	8,883,137	PAPR	137	14	0.6
7	Chemical products	7,203,549	5,427,942	CHEM	187	16	0.6
8	Petroleum and coal products	23,049,246	14,238,485	PETR	3,559	17	0.6
9	Rubber, plastic, and leather products	2,384,840	1,988,938	CHEM	76	20	0.7
10	Clay, stone, glass, and concrete products	27,244,806	18,450,534	STON	1,366	17	0.6
11	Primary metal products	1,942,665	1,537,813	PMTL	122	13	0.5
12	Fabricated metal products	1,997,253	1,982,819	FMTL	56	28	0.8
13	Machinery and transportation equipment	6,835,576	6,282,549	MACH	53	17	0.6
14	Instruments, and miscellaneous manufacturing products	862,667	799,874	INST	7	23	0.8

Code	CG Name	2013 I-E Tonnage	2013 Estimated	Variable Name(s)	Coeff	t-Stat	R^2
15	Waste and scrap materials	12,806,910	12,332,138	TOTAL	3	69	1
16	Mail, freight forward, and miscellaneous freight shipments	6,674,796	13,601,411	SERV	7	21	0.7
18	Bulk movement, secondary, intermodal, and warehouse traffic	30,438,825	56,654,810	TOTAL	14	27	0.8
All	**Summation**	**238,798,666**	**205,197,134**				

The graphs showing regression analysis for each commodity group are presented and discussed in Appendix D.

5.3.5 Commodity Freight Attraction Equations

As discussed earlier, for this update of the GSTDM, only one new equation for attractions was developed using the 2013 Georgia TRANSEARCH as the estimation dataset. Reported attractions for all 159 counties in Georgia were used as regression observations, and no observation was removed from the regression. The attraction equations were fit to observed annual tonnage for 17 of the 18 CGs, with GSTDM SE data (e.g. employment by category, population, total employment) as the explanatory variables. The attraction equations are shown in Table 5-6. No tonnages were reported as attracted for CG 17, HAZMAT, and no equations could be developed.

Table 5-6: Attraction Coefficients by Commodity Group

Code	CG Name	2013 I-E Tonnage	2013 Estimated	Variable Name(s)	Coeff	t-Stat	R^2
1	Agriculture products	23,142,108	13,954,646	FOOD	243	15	0.6
2	Non-metallic mining	71,401,110	48,136,378	STON	2,694	14	0.6
3	Food and tobacco products	22,312,276	25,044,186	POP	2	24	0.8
4	Textile and apparel products	1,318,182	1,523,441	WSLE	7	20	0.7

Code	CG Name	2013 I-E Tonnage	2013 Estimated	Variable Name(s)	Coeff	t-Stat	R^2
5	Lumber, wood, and furniture products	14,147,181	13,958,057	POP	1	14	0.6
6	Paper and printing products	9,070,278	9,507,647	WSLE	24	23	0.8
7	Chemical products	13,889,876	12,178,003	WSLE	42	18	0.7
8	Petroleum and coal products	23,136,616	24,166,744	POP	2	23	0.8
9	Rubber, plastic, and leather products	2,016,168	2,397,656	WSLE	12	26	0.8
10	Clay, stone, glass, and concrete products	21,390,928	27,113,357	POP	2	18	0.7
11	Primary metal products	3,557,114	2,860,655	FMTL+MACH	31	20	0.7
12	Fabricated metal products	1,574,074	1,866,860	MACH	28	18	0.7
13	Machinery and transportation equipment	6,348,155	6,182,597	WSLE	27	16	0.6
14	Instruments, and miscellaneous manufacturing products	685,062	972,767	WSLE	5	28	0.8
15	Waste and scrap materials	8,311,184	7,757,916	POP	0	17	0.6
16	Mail, freight forward, and miscellaneous freight shipments	7,298,488	14,166,084	SERV	7	22	0.8

Code	CG Name	2013 I-E Tonnage	2013 Estimated	Variable Name(s)	Coeff	t-Stat	R^2
18	Bulk movement, secondary, intermodal, and warehouse traffic	33,097,057	54,798,120	WSLE	268	19	0.7
All	Summation	262,695,855	266,585,115				

5.3.6 Special Generator Freight Productions and Attractions

The tonnages in the 2013 Georgia TRANSEARCH database, by commodity group, as reported for 2013, are from Georgia to external (i.e., outside of Georgia) zones, and to Georgia from external zones, and are not computed using the proposed equations. Instead, all the production or attraction tonnages associated with these external zones are treated as special external generators at these external zones utilizing values from 2013 TRANSEARCH. The values are scaled upwards, or downwards, based on the changes in productions and attractions of freight by commodity group within Georgia as forecast by the production and attraction equations. This step is included in the balancing of productions and attractions that must precede the use of a gravity model in trip distribution. There is no way to determine if the proposed equations should apply to external zones, or if the values in external zones are due to special generators that are not consistent with the explanatory variables (e.g., productions or attractions at a port in an external zone that has no explanatory employment). It also is not reasonable to expect GDOT to maintain base and forecast year detailed socioeconomic data for those external zones not under its jurisdiction.

Appendix D contains the commodity freight production and attraction regression equations. In addition to special generators that are the external zones, there are outliers to the proposed commodity group equations for productions and attractions, shown as red dots in Figures 1-1 through 1-36 in Appendix D. The difference between the estimated production (or attraction) and observed value was first filtered to remove differences whose absolute value is within one-third of the maximum value. This is intended to filter out differences that are only due to statistically expected variations An additional filter was applied to identify those outliers whose absolute value of the proposed special generator using this method is less than 5 percent of the sum of all special generator outliers for a commodity group. This is intended to remove any potential special generator whose value would be minimal compared to the estimated value. The remaining outliers, by commodity group, were assumed to be potential special generator outliers included within those observed FIPS values. Since this outlier is by FIPS county code, it is necessary to identify the TAZ in which the special generator is located to meet its intended use in the model.

The assumption is that if there is an intermodal terminal in that FIPS county, then that is the likely special generator. Those locations were identified by combining the point shapefile of freight facilities from the National Transportation Atlas database and the intermodal terminals from the Oak Ridge National Laboratories/Center for Transportation Analysis with the polygon shapefile of GSTDM TAZs. This provides the list of possible intermodal terminals in a county by

TAZ. Only special generators whose proposed values are positive can be assumed to be occurring at intermodal terminals.

If there is no intermodal terminal in a FIPS, it is assumed that the special generator is in the TAZ that has the largest value for the explanatory variable. If the outlier special generator value is positive, it can be assumed that the employment center is highly productive/automated (because the rates will be expressed in tons per employee). If the special generator value is negative, it is assumed that the employment center is highly unproductive (in terms of tons per employee). This could occur, for example, if the employment center had a large portion of administrative employees that, while in that GSTDM industry, do not make or consume freight.

The list of proposed special generators by commodity group and their assignment to TAZs for productions is shown in Table 5-7, and special generator attractions are shown in Table 5-8. Also included in these tables, under the comment heading, is the location of the facility that is the basis for this determination for reference.

Table 5-7: Production Special Generators

GC Code	CG Name	SG County	SG Tons	Comment
01	Agriculture products			No SGs
02	Non-metallic mining	Jones	2,722,062	Need TAZ with largest MING employment in this FIPS
		Talbot	877,692	Need TAZ with largest MING employment in this FIPS
		Muscogee	135,719	TAZ 13215 NS Bulk Columbus
		Crawford	283,714	TAZ 273 NS Bulk Doraville
		Richmond	46,673	Need TAZ with largest MING employment in this FIPS
03	Food and tobacco products	Chatham	1,574,324	TAZ 1586 Ocean Terminal
04	Textile and apparel products	Chatham	523,309	TAZ 1586 Ocean Terminal
05	Lumber, wood, and furniture products	Chatham	696,815	TAZ 1586 Ocean Terminal
		Ware	318,035	Need TAZ with largest LUMB employment in this FIPS
		Wheeler	354,853	Need TAZ with largest MING employment in this FIPS
		Lowndes	298,602	TAZ 1697 Yellow Valdosta
		Colquitt	193,107	Need TAZ with largest LUMB employment in this FIPS
		Jefferson	216,807	Need TAZ with largest LUMB employment in this FIPS

GC Code	CG Name	SG County	SG Tons	Comment
		Jeff Davis	156,252	Need TAZ with largest LUMB employment in this FIPS
06	Paper and printing products	Chatham	1,076,007	TAZ 1586 Ocean Terminal
		Wayne	875,986	Need TAZ with largest PAPR employment in this FIPS
		Richmond	339,016	Need TAZ with largest PAPR employment in this FIPS
		Floyd	356,659	TAZ 1637 Port of Brunswick
		Glynn	310,262	TAZ 1277 Saddle Creek
		Bibb	183,460	Need TAZ with largest PAPR employment in this FIPS
		Early	271,926	Need TAZ with largest PAPR employment in this FIPS
07	Chemical products	Chatham	926,271	TAZ 1536 CSXT Bulk Transflo Savannah
		Richmond	898,008	TAZ 1214 IndChem Bulk
		Fulton	(203,739)	TAZ 47 CSXT Atlanta Bulk Transflo
08	Petroleum and coal products	Hall	2,656,873	Need TAZ with largest PETR employment in this FIPS
		Chatham	881,407	TAZ 394 NS Austell
09	Rubber, plastic, and leather products	Chatham	427,279	TAZ 1586 Ocean Terminal
		Polk	21,000	Need TAZ with largest RUBB employment in this FIPS
10	Clay, stone, glass, and concrete products	Washington	1,169,631	Need TAZ with largest STON employment in this FIPS
		Houston	844,803	Need TAZ with largest STON employment in this FIPS
		Elbert	653,891	Need TAZ with largest STON employment in this FIPS
		Jefferson	560,701	Need TAZ with largest STON employment in this FIPS
11	Primary metal products	Chatham	855,812	TAZ 1596 Savannah River Wharf
		Bartow	111,349	Need TAZ with largest PMTL employment in this FIPS
		Muscogee	51,243	Need TAZ with largest PMTL employment in this FIPS
12	Fabricated metal products	Chatham	498,043	TAZ 1596 Savannah River Wharf
13	Machinery and transportation equipment	Chatham	1,635,613	TAZ 1586 Ocean Terminal
		Glynn	801,668	TAZ 1637 Port of Brunswick
		Troup	550,255	Need TAZ with largest MACH employment in this FIPS
14	Instruments, and miscellaneous	Chatham	349,131	TAZ 1586 Ocean Terminal

GC Code	CG Name	SG County	SG Tons	Comment
	manufacturing products	Bibb	50,996	TAZ 1277 Saddle Creek
15	Waste and scrap materials			NoSGs
16	Mail, freight forward, and miscellaneous freight shipments			No SGs
17	Waste hazardous substances and hazardous materials	Bartow	11,290	Need TAZ with largest SERV employment in this FIPS
18	Bulk movement, secondary, intermodal, and warehouse traffic	Fulton	233,143	TAZ 46 NS Atlanta Inman

Table 5-8: Attraction Special Generators

GC Code	CG Name	SG County	SG Tons	Comment
01	Agriculture products	Chatham	807,426	TAZ 1586 Ocean Terminal
		Mitchell	88,434	TAZ 2641 Central State Grain
		Lowndes	453,211	TAZ 1684
		Fulton	-343,159	TAZ 6
		Gordon	179,329	TAZ 1834
		Habersham	136,687	Need TAZ with largest FOOD employment in this FIPS
		Gwinnett	1,464,162	Need TAZ with largest STON employment in this FIPS
03	Food and tobacco products	Chatham	3,078,543	TAZ 1586 Ocean Terminal
		Fulton	876,183	TAZ 46 NS Atlanta Inman
		Glynn	253,512	Need TAZ with largest Population in this FIPS
04	Textile and apparel	Fulton	29,984	TAZ 46 NS Atlanta Inman
		Whitfield	129,918	TAZ 1141 NS Dalton Railer

GC Code	CG Name	SG County	SG Tons	Comment
	products	Chatham	63,668	TAZ 1586 Ocean Terminal
		Gwinnett	-42,090	Need TAZ with largest WSLE employment in this FIPS
05	Lumber, wood, and furniture products	Chatham	1,674,392	TAZ 1586 Ocean Terminal
		Glynn	699,593	TAZ 1637 Port of Brunswick
		Wayne	554,990	TAZ 2586
		Richmond	258,796	TAZ 1194 CSXT Augusta Bulk
06	Paper and printing products	Chatham	4,715,342	TAZ 1586 Ocean Terminal
07	Chemical products	Chatham	1,651,582	TAZ 1586 Ocean Terminal
		Muscogee	1,492,111	TAZ 1350 St Services (WR Grace) Columbus
		Richmond	674,850	TAZ 1214 IndChem Bulk
09		Chatham	36,799	TAZ 1586 Ocean Terminal
10	Clay, stone, glass, and concrete products	Chatham	2,202,397	TAZ 1584 Southern Bulk
11	Primary metal products	Chatham	52,549	TAZ 1596 Savannah River Wharf
		Carroll	29,143	
12	Fabricated metal products	Fulton	84,996	TAZ 47 CSXT Atlanta Bulk
		Chatham	38,350	TAZ 273 NS/Matlack Doraville Bulk
13	Machinery and transportation equipment	Chatham	428,168	TAZ 1586 Ocean Terminal
		Glynn	299,017	TAZ 1637 Port of Brunswick
14	Instruments, and miscellaneous manufacturing products	Fulton	214	TAZ 46 NS Atlanta Inman
		Chatham	87	TAZ 1596 Savannah River Wharf
15	Waste and scrap materials	Chatham	941,723	TAZ 1596 Savannah River Wharf
		Troup	843,596	TAZ 2060
		Bartow	157,788	TAZ 844
		Peach	151,442	Need TAZ with largest Population in this FIPS

GC Code	CG Name	SG County	SG Tons	Comment
16	Mail, freight forward, and miscellaneous freight shipments	No SGs		
17	Waste hazardous substances and hazardous materials		n/a	
18	Bulk movement, secondary, intermodal, and warehouse traffic	Fulton	2,937,837	TAZ 46 NS Atlanta Inman
		Gwinnett	-1,802,239	TAZ 253

5.4 COMMODITY DISTRIBUTION MODEL

The GSTDM freight gravity models, or commodity trip distribution equations, were developed using the Georgia 2013 TRANSEARCH database. The average trip lengths that are needed to obtain trip length frequency distributions and the associated friction factors were obtained from Georgia 2013 TRANSEARCH. For truck commodity flows, 2013 Georgia TRANSEARCH already includes the average miles traveled between its regions. For the other freight modes, those distances needed to be added. Those distance mileages were taken from the county-to-county distance skims reported by the Oak Ridge National Laboratory's (ORNL) Center for Transportation Analysis.[13] In the event that a TRANSEARCH region included multiple counties, the dominant freight county in that region was identified, and the modal distance between that county and a Georgia FIPS was used as the interregional distance. The rail distances were taken as the sum of the rail miles (U.S.) and the rail miles (outside U.S.) in the ORNL dataset. Because TRANSEARCH only reports unlinked rail trips, these distances were used for both rail carload and rail intermodal (IMX) flows. For water, the intercounty water miles were used. For all other modes (air, other, pipeline, etc.), the great circle distances reported between counties were used. The multimodal average trip lengths by commodity group were estimated from the Georgia 2013 TRANSEARCH updated miles.

For the GSTDM, trip distribution was estimated at the county level. The external zones for the rest of the U.S., Canada, and Mexico are consistent with the zonal system included in the

[13] *Center for Transportation Analysis, County-to-County Distance Matrix, Oak Ridge National Laboratory, http://cta.ornl.gov/transnet/SkimTree.htm.*

Georgia 2013 TRANSEARCH. This means that TRANSEARCH regions nest within the GSTDM external TAZs. Given that the GSTDM zones do not include Canada and Mexico, a crosswalk was developed to assign those TRANSEARCH zones to the nearest GSTDM border TAZ.

5.4.1 Friction Factors

The friction factors to be used in freight distribution are calculated as a negative exponential function of the average travel distance from origin zone to destination zone. The parameters in the exponential function are estimated by calculating the average travel length for all external-internal (E-I), internal-external (I-E), and internal-internal (I-I) trips for each commodity group. The average impedance value for each commodity type was determined by multiplying the average distances by the annual tonnage from TRANSEARCH for each record and summing those values by commodity group over all records. The resulting matrix of ton-miles was then divided by the total tonnage for that same commodity group. The impedance value and average travel length for each commodity group is shown in Table 5-9 along with actual model results.

Table 5-9: Impedance Values by Commodity Group

Code	Commodity Group	2013 Average Trip Length (miles)	Friction Factor Coefficient	Model Results	Percent Difference
1	Agriculture products	472.1	-0.0021182	536.6	13.7%
2	Non-metallic mining	206.7	-0.0048369	385.8	86.6%
3	Food and tobacco products	554.1	-0.0018048	633.8	14.4%
4	Textile and apparel products	702.6	-0.0014233	733.7	4.4%
5	Lumber, wood, and furniture products	318.6	-0.0031392	454.1	42.6%
6	Paper and printing products	529.7	-0.0018877	580.4	9.6%
7	Chemical products	537.9	-0.0018590	616.7	14.6%
8	Petroleum and coal products	207.3	-0.0048252	333.8	61.1%
9	Rubber, plastic, and leather products	647.1	-0.0015454	644.3	-0.4%
10	Clay, stone, glass, and concrete products	313.8	-0.0031867	379.7	21.0%
11	Primary metal products	511.1	-0.0019565	558.1	9.2%
12	Fabricated metal products	490.9	-0.0020370	522.5	6.4%
13	Machinery and transportation equipment	621.2	-0.0016098	648.4	4.4%
14	Instruments, and miscellaneous manufacturing products	681	-0.0014685	646.2	-5.1%
15	Waste and scrap materials	305.4	-0.0032740	415.5	36.0%
16	Mail, freight forward, and miscellaneous freight shipments	811.4	-0.0012325	523.3	-35.5%

Code	Commodity Group	2013 Average Trip Length (miles)	Friction Factor Coefficient	Model Results	Percent Difference
18	Bulk movement, secondary, intermodal, and warehouse traffic	251.4	-0.0039781	136	-45.9%

For each commodity group, the reciprocal of the resulting average distance was used in calculating the friction factors. The equation to calculate friction factors for each origin-destination (OD) pair for each commodity group is shown as follows:

$$FF_{cij} = \exp(-(1/ATL_{c})*dd_{ij})$$

Where:

FF_{cij} = Friction factor for O-D pair *ij* and commodity group *c*,

ATL_{c} = Average travel length for commodity group *c*, and

d_{ij} = GSTDM highway distance for O-D pair *ij*.

5.4.2 Conversion of Freight Production-Attraction (PA) Tables to O-D Tables

The end result of the trip distribution process are tables of freight shipments, by commodity group, between the zones in which tonnages are produced and the zones in which they are consumed. In passenger applications, prior to the assignment and/or mode choice steps, these PA tables are often converted to O-D tables by transposing the PA table and combining the original table multiplied by the percentage of productions that are origins in that time period and the transposed table multiplied by the percentage of attractions that are destinations in that time period. For an average daily table, those percentage splits typically are 50 percent/50 percent. The concept of splitting and transposing is necessary because the productions of home-based passenger trips, work and other, include both the origin from home and the return trip to home (e.g., a home-based work production is the origin trip end from home to work, and the destination trip end returning from work to home). In passenger modeling, this splitting and transposing from PA to O-D tables should never be done for non-home-based trips. For freight commodity trips in annual tons, where commodities have no economic reason to make a round trip back to the origin, the PA table is already an O-D table and no splitting and transposing needs to be done, and consequently is not done.

5.5 FREIGHT MODE CHOICE

The standard method of developing future year mode splits is to develop a logit model of mode choice based on the utilities of the competing modes. The coefficients of the utility equations typically are developed by fitting the observed mode shares to the modal utilities.

An incremental logit choice model provides the ability to take maximum advantage of the ability to forecast change in explanatory variables, as well as the variability in the modal constants, which would be considered in the existing mode share. The existing mode share can be determined from the Georgia TRANSEARCH database. The relative change in utility can be computed for each commodity group using changes in the modal utility between an origin and a destination resulting from changes in cost and time for that travel. The incremental logit model is widely used in passenger travel demand forecasting and is well-suited to this application. In passenger applications, utility equations need only to be specified for modes where the utility is expected to change truck and rail modes in the proposed freight application, and do not have to be specified for modes were utility is not expected to change air and water modes in the proposed freight application. There may be commodity/origin/destination combinations where freight movements are forecasted, but there are no existing shipments in the TRANSEARCH database making an incremental application impossible. In such cases, the logit mode choice model will be applied directly to the freight forecasts using the average mode-specific shares estimated from the TRANSEARCH database.

The incremental logit model takes the form of

$$\mathrm{S}'_{\mathrm{ijm}} = \frac{S_{ijm} * \exp\left(\Delta U_{\mathrm{ijm}}\right)}{\sum_{m}^{M} S_{ijm} * \exp\left(\Delta U_{\mathrm{ijm}}\right)}$$

Where:

S'_{ijm} = New share of the flows carried by mode *m* between zone *i* and zone *j*,

S_{ijm} = Existing share of the flows carried by mode *m* between zone *i* and zone *j*; and

U_{ijm} = Utility from *i* to *j* of mode *m* among all modes *m*, which also is stated as:

*Modal Constant m + bv * ExplVarv ijm*

Where:

b^{v} = Coefficient for *ExplVar v* (e.g., travel time); and

$ExplVar^{v}_{ijm}$ = Explanatory Variable *v* (e.g., travel time) for mode *m* between zone *i* and zone *j*.

5.5.1 Existing Mode Shares

The GSTDM freight mode choice model is an incremental mode choice model. As such, it requires a table of existing mode shares. The required table of existing mode shares is developed directly from the table of modal freight tonnage flows by origin, destination, commodity group, and mode, which is prepared as the model estimation file. This file is not designed to report freight flows in tons but as the percent share by a mode for a given origin, destination, and commodity group combination.

Mode shares in percentages are presented in Table 5-11. The truck model is the most dominant mode that carries 70 percent of all freight in the state, followed by intermodal and carload rail at 15 percent and 14 percent, respectively. As expected, the share of freight being transported by water and air are very small – 0.04 and 0.005 percent, respectively.

The mode shares for external to external travel through Georgia should not change based on changes in Georgia's socioeconomic data as these trips pass through Georgia without stopping. Given that the data for external areas to Georgia is either unavailable or less reliable, the base year external-external freight tables were also developed from the Georgia 2013 TRANSEARCH database and are used directly outside the mode choice procedure.

5.5.2 Calculation of Modal Costs

Table 5-10 gives the modal costs in dollars for the shippers, which are used to derive the shipping cost between each GSTDM county-to-county O-D pair. Shipping cost per ton-mile for trucks was calculated using the Bureau of Transportation Statistics (BTS) rates. The BTS truck cost for shippers is $0.1314 per ton-mile with zero-dollar fixed cost. Distance skims were used to calculate the cost for each O-D pair.

The carload and intermodal shipping cost was derived from STB. Drayage cost also must be added into the cost for the shipper, which was at $200 per load. Assuming 18 tons per container, then the drayage cost is $11.11 per ton. It was assumed that there would be a dray at each end of the trip, which would increase the fixed cost by $22.22 per ton. When added to the intermodal fixed cost above, the total intermodal rail cost is $46.89 + $0.045 per ton-mile. Rail distance skims were used to calculate the carload and intermodal cost for each O-D pair. These values are presented in Table 5-10 below.

Table 5-10: Modal Costs to Shippers

Modal Classification	Fixed Cost (Dollar per Ton)	Variable Cost (Dollar per Ton-Mile)
Truck	0.00	**0.1314**
Carload Rail	16.10	**0.0234**
Intermodal Rail	**46.89**	**0.0450**

5.5.3 Calculation of Modal Times

Travel time for each county-to-county O-D pair was derived from the highway distance skims for trucks and from rail distance skims for carload and intermodal rail.

Truck travel time outside of Georgia, where the GSTDM does not forecast traffic performance, was estimated as:

*Truck Travel Time = highway distance/50 mph + truncate ((highway distance/50 mph)/10) * 14.*

This formula represents travel at 50 mph and a 14-hour rest period after every 10 hours of travel, as a simplification of the Federal Hours of Service (HOS) regulations.

The relationships between distance and time for carload and intermodal rail were adapted from the Florida Intermodal Statewide Highway Freight Model (FISHFM).[14] The FISHFM model determined carload rail time to be 60 hours plus highway distance per 20 mph and determined intermodal rail time to be 24 hours + highway distance per 22.75 mph. It was desirable to use rail distances in the GSTDM to derive carload and IMX time, rather than highway distances that were used in the FISHFM model. The relationship between highway distance and rail distance is approximately 1.08 rail distance to 1.0 highway distance; therefore, the speeds in the FISHFM model are multiplied by 1.08. In addition, the FISHFM equation is modified for intermodal by adding a one-hour drayage time to both ends of the intermodal time. Therefore, the final GSTDM formulas for deriving carload and intermodal rail time from rail distance are the following:

Carload Rail Time = 60 hours + rail distance/21.72 mph

Intermodal Rail Time = 24 hours + 2 hours intermodal dray + rail distance/24.75 mph

The utility equations of mode choice used estimates for only truck, carload rail, and intermodal rail freight. The incremental (pivot point) mode choice model includes the existing mode share of all modes, including air and water. Because there is no calculation of a change in utility for air and domestic water, the numerator of the mode choice model will be the existing mode share for air and domestic water; however, since the numerator includes the modes for which changes in utility are calculated, the forecast mode share of air and domestic water is allowed to vary. Table 5-11 shows the comparison between the 2013 Georgia TRANSEARCH and 2015 GSTDM mode share.

Table 5-11: TRANSEARCH 2013 – GSTDM Mode Share Comparison

Mode	Share	
	TRANSEARCH 2013	Model

[14] *Cambridge Systematics, Florida Intermodal Statewide Highway Freight Model: Technical Memorandum Task 3 – Model Specification, Tallahassee, Florida, Florida Department of Transportation, 2002.*

Mode	Share	
Truck	86.0%	80.5%
Carload Rail	12.2%	15.7%
Intermodal Rail	1.1%	3.8%

5.6 FREIGHT TRUCK ASSIGNMENT

After mode choice, a table of truck tons to and from Georgia counties and other Georgia counties and zones external to Georgia is created, in addition to tables for other modes. To assign the trucks to the highway system, additional processing is required.

The annual tons must be converted to average weekday tons. This is done using the existing factor in the GSTDM of 306 equivalent weekdays per year.

The weekday truck tons are converted to weekday trucks using the tons per trucks by commodity group, as reported in the 2013 TRANSEARCH shown in Table 5-12.

Table 5-12: Tons per Truck by Commodity Group

	Commodity Group	Tons per Truck
1	Agriculture products	16.91
2	Non-metallic mining	24.31
3	Food and tobacco products	22.93
4	Textile and apparel products	20.05
5	Lumber, wood, and furniture products	24.40
6	Paper and printing products	23.18
7	Chemical products	20.85
8	Petroleum and coal products	24.16
9	Rubber, plastic, and leather products	11.94
10	Clay, stone, glass, and concrete products	16.24
11	Primary metal products	24.90
12	Fabricated metal products	17.97

	Commodity Group	Tons per Truck
13	Machinery and transportation equipment	14.36
14	Instruments, and miscellaneous manufacturing products	16.21
15	Waste and scrap materials	23.92
16	Mail and miscellaneous freight shipments	20.56
17	Waste hazardous substances and hazardous materials	N/A
18	Bulk movement, secondary, intermodal, and warehouse traffic	17.06

6. NON-FREIGHT TRUCK MODEL

In addition to the trucks that carry freight, the GSTDM also forecasts the demand of trucks that do not carry freight, for example, service, maintenance, and construction trucks. These trucks also contribute to roadway congestion, and these trucks often have larger volumes on the road network than the trucks that carry freight, particularly in urban areas. These trucks primarily travel shorter distances than the trucks that carry freight. For use in estimating a model of non-freight trucks, the focus was on truck trips that begin or end in Georgia which also is known as internal-internal (I-I) truck trips.

6.1 NON-FREIGHT TRUCK GENERATION

In order to consider truck trips in travel demand modeling, the 1996 edition of the Quick Response Freight Manual (QRFM)[15] proposed rates that could be used to forecast trip ends (for trucks, as is true for non-home-based passenger trips, the same trip rates are used to forecast origins/productions and destinations/attractions). That table of truck trip rates is shown in Table 6-1.

Table 6-1: QRFM Trip Generation Rates

Generation Variable	Commercial Vehicle Trip Destinations (or Origins) per Unit per Day			
	Four-Tire Trucks	Single Unit Trucks (6+ Tires)	Combination Trucks	Total
Agriculture, Mining and Construction	1.110	0.289	0.174	1.573
Manufacturing, Transportation, Communications, and Utilities and Wholesale Trade	0.938	0.242	0.104	1.284
Retail Trade	0.888	0.253	0.065	1.206
Office and Services	0.437	0.068	0.009	0.514
Households	0.251	0.099	0.038	0.388

The employment categories listed in Table 6-1 are based on the Standard Industrial Classification (SIC) categories that were in common usage in the 1990s. Those have been replaced by the employment and firm categories in the NAICS. This system is a hierarchical system where additional digits provide additional detail, but the employment data can be aggregated to categories with fewer digits of detail. NAICS two-digit classifications corresponding to SIC QRFM categories listed in Table 6-1 are shown in Table 6-2.

15 *Cambridge Systematics, et al.; Quick Response Freight Manual (QRFM); Federal Highway Administration, Office of Planning and Environment; September 1996.*

Table 6-2: Equivalency between QRFM and GSTDM Variable

QRFM Category	GSTDM Equivalent
Employment	NAICS2 Code
Agriculture, Mining and Construction	11, 21, 23
Manufacturing, Transportation, Communications, Utilities and Wholesale Trade	31-33, 48, 51, 22, and 42
Retail Trade	43
Office and Services	52-92
Households	Occupied Dwelling Units

The freight portion of the GSTDM update was estimated using NAICS3 employment as the explanatory data. These data were developed for individual TAZs in Georgia but can be aggregated to the counties containing those TAZs in order to develop rates and determine the degree of correlation. The NAICS3 employment data by TAZ that were developed for the freight portion of the GSTDM were aggregated to counties and to NAICS2 categories for purposes of developing rates and preparing correlations for freight and non-freight trucks. The correspondence between the QRFM variables and the NAICS2 categories is shown in Table 6-2.

ATRI/StreetLight GPS data, which are used to refine the QRFM rates in other statewide models were not available for Georgia. It was decided to borrow the ATRI/StreetLight data from the Virginia and Mississippi models, which were recently completed. Ideally, Georgia specific data would be obtained to allow refinement of the QRFM data to Georgia conditions. Only heavy (combination) trucks in the GPS O-D truck estimation database are expected to be highly correlated to the QRFM rates. This is because, while the actual trucks estimated for GPS origins and destinations is not known, ATRI has stated that more than 88 percent of the trucks reported to ATRI are heavy combination trucks (Classes 7 and 8 using the BTS/VIES gross vehicle weight classification of trucks). It is proposed that the relationship between the rates derived from a regression of the ATRI Origins, which also should be true for destinations, and the QRFM variables for heavy trucks would be the same relationship that should be assumed to be applied to the QRFM rates for medium, single unit trucks.

The rates for light four-tire (pickup) trucks are not computed for the GSTDM. Trucks of this size and type are primarily used for personal (i.e., passenger, travel). Nationally, personal use of these trucks accounts for over 75 percent of the vehicle miles of travel (VMT) by all “light” trucks. Additionally, it is not possible to separate unobtrusive observations of light trucks into personal and commercial purposes. For these reasons, it is presumed that the estimation of light trucks for personal usage should be the preferred means to estimate and validate the demand and usage of light trucks.

6.1.1 Correlation of GPS Data versus GSTDM Variables

The expanded processed GPS O-D truck trips by TAZ for these non-freight truck employment categories were aggregated to counties in Virginia. This is because eventually heavy truck trips end by freight are reported by TRANSEARCH, whose most detailed level of geography within Virginia is county. While the medium and heavy truck tables were used directly, the non-freight heavy truck trip ends at a county level were estimated by subtracting the TRANSEARCH reported trip ends, converted to weekday truck trips, from the Origin Destination Matrix Estimation (ODME) expanded GPS heavy truck trip ends.

The regressions use household and total employment as explanatory variables for both single unit and non-freight combination unit trucks. Each variable is used individually as a variable for trip generation for single unit trucks. This is not the case for non-freight combination trucks.

For non-freight combination trucks, households and employment when used individually correlated well with the expanded non-freight truck trip ends. However, it is reasonable to assume that some TAZs will have only households and no employment and vice versa for other TAZs. Therefore, it would be desirable to use both variables as explanatory variables in computing non-freight combination truck trip ends. However, when a standard multilinear regression was performed, the coefficient for at least one variable, employment, became negative and thus cannot be used. When a non-linear least squares method is used that is constrained to non-negative coefficients, the result is a zero value for one coefficient and a coefficient for the other variable that is similar to the value found from the standard multiple linear regression. To address this problem, a single explanatory variable was tested and eventually recommended for use in the non-freight combination truck model. The variable is the sum of households and total employment in a TAZ, aggregated to counties prior to regression.

The non-freight truck trip generation rates used in the VSTM are shown in Table 6-3.

Table 6-3: GSTDM Non-Freight Trip Generation Rates

GSTDM Variable	Medium Single Unit Trucks (6+Tires)	Heavy Non-Freight Combination Trucks
Households Coefficient	0.013	N/A
Employment Coefficient	0.042	N/A
Employment plus Households Coefficient	N/A	0.016
R2 (Coefficient of Determination)	0.911	0.617

6.2 NON-FREIGHT TRUCK DISTRIBUTION

Trip distribution is the process by which trips between TAZs, or between external stations, are connected. The output of trip distribution is a trip table in which the origins and destinations of individual trips are identified.

The 1996 QRFM procedure uses the following standard gravity model for trip distribution:

$$V_{ij} = \frac{O_i D_j F_{ij}}{\sum_{j=1}^{n} D_j F_{ij}}$$

Where:

V_{ij} = Trips (volume) originating at analysis area *i* and destined to analysis area *j*;

O_i = Total trip originating at *i*;

D_j = Total trip destined at *j*;

F_{ij} = Friction factor for trip interchange *ij,*

i = Origin analysis area number, *i* = 1, 2, 3, … *n*;

j = Destination analysis area number, *j* = 1, 2, 3, … *n*; and

n = Number of analysis areas.

Friction factors (F_{ij}) for use with the gravity model can be based on travel time or distance between analysis areas. The GSTDM highway network includes link travel times that can be used to compute the required travel times between TAZs. In the quick response method for the different types of commercial vehicles, the following friction factors based on travel time, t_{ij}, in minutes between analysis areas are recommended:

Single-unit trucks (6+tires):

$$F_{ij} = e^{-0.1 * t_{ij}}$$

Combinations:

$$F_{ij} = e^{-0.03 * t_{ij}}$$

The coefficients in these equations are defined as the negative inverse of the average trip length for that class of trucks. It is assumed that the scaling of 1.5 that represented the correlation between the QRFM rates and the observed adjusted non-freight truck trip ends also should be applied to the QRFM average trip lengths. The proposed GSTDM non-freight truck distribution parameters for friction factors are shown in Table 6-4.

Table 6-4: Impedance Values for Non-Freight Trucks

Trip Distribution Parameters	Single Unit Trucks (6+ Tires)	Combination Trucks
QRFM		
Coefficient	-0.10	**-0.03**
Average Trip Length (ATL) (in minutes)	10.00	**33.33**
GSTDM		
Coefficient	-0.08	**-0.02**
ATL (in minutes)	**12.5**	**50**

6.3 TRUCK ASSIGNMENT

In the GSTDM all heavy and medium trucks, including freight as output from mode choice and converted from annual tons to daily trucks, are assigned to the highway network. The treatment of rail assignment is unchanged from the previous model, where the total tons are assigned to a rail network. Note that this assignment should primarily be used for illustrative purposes to convey a sense of the magnitude of rail flows through the state. Direct validation comparisons to actual rail flows are not possible or advisable, given the unique characteristics of rail dispatching within each respective company and the desire to keep traffic moving on their own property. The absence of public assignment data from each railroad company also is another difficulty. Other modes are available for assignment, but the GSTDM does not have networks associated with these modes and they are consequently not assigned.

The freight trucks are assigned to the highway network along with all vehicles and are subject to the same link assignment rules as single and multi-occupant (auto) vehicles. The combined assignment of all trip tables is through a multimodal, multiclass assignment (MMA). The total truck link volumes that are assigned are within the validation ballpark of the classified and estimated counts from GDOT's traffic count sources.

Figure 6-1 and Figure 6-2 illustrate the daily assigned 2015 truck flows resulting from the current freight model update at the Atlanta region and statewide scale, respectively. Table 6-5 shows the aggregate validation statistics for trucks and a comparison with ranges observed from other statewide models.

Table 6-5: Final Truck Validation Values

Facility Type	%RMSE	vol/cnt	Number of Truck Count Locations	Other SWMs %RMSE Range	Other SWMs vol/cnt Range
Interstates	22.6	1.07	234	22 - 95	0.9 - 1.30
Freeways	27.2	1.03	27	27 - 100	
Other Principal Arterials	57.8	1.11	931	57 - 250	
Minor Arterials	111.7	1.06	817	n/a	
Collectors	187.2	0.91	1,226	n/a	1
All	**63.9**	**1.07**	**3,282**	**60 - 135**	**0.9 - 1.30**

Figure 6-1: Atlanta Region 2015 Daily Truck Volumes

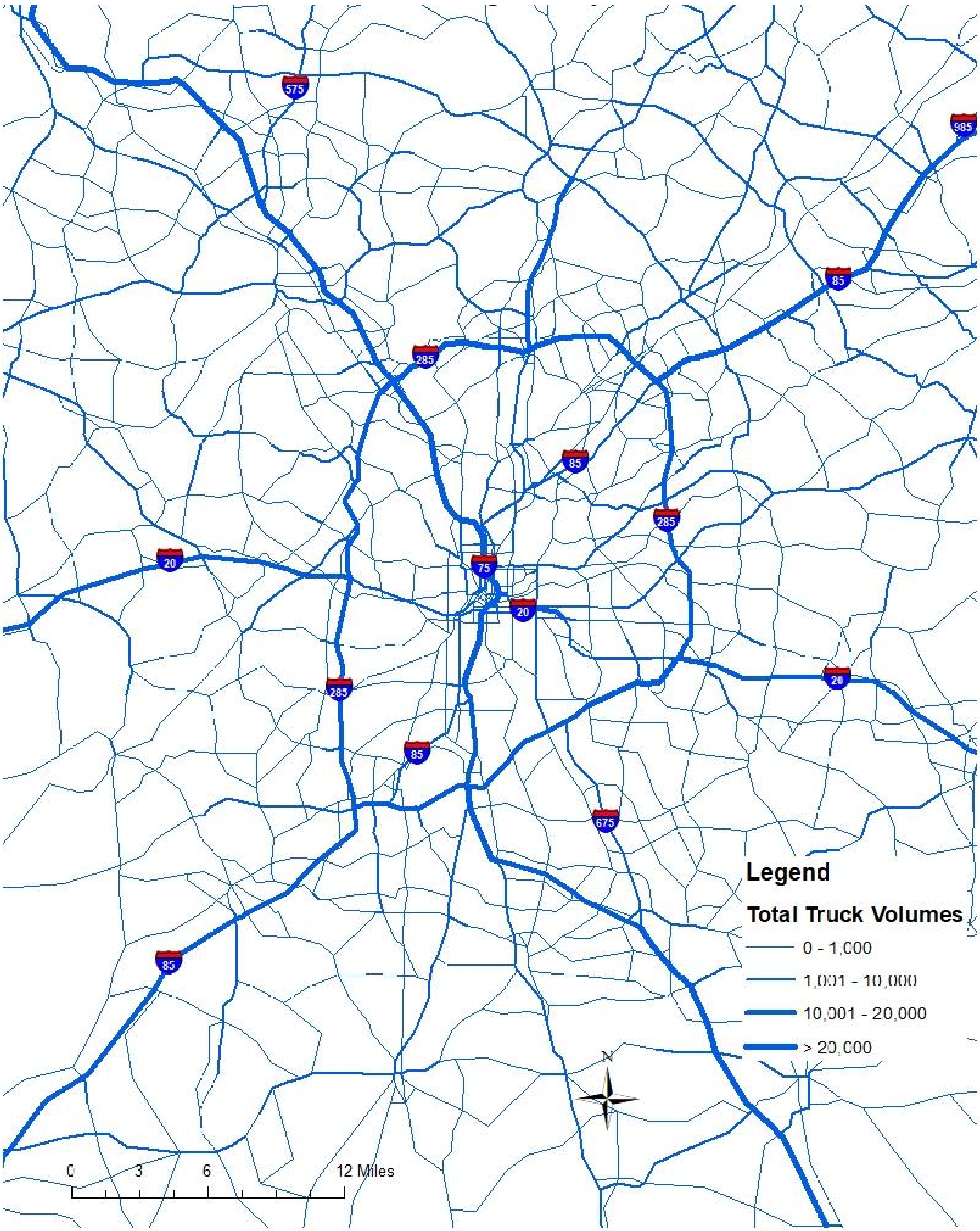
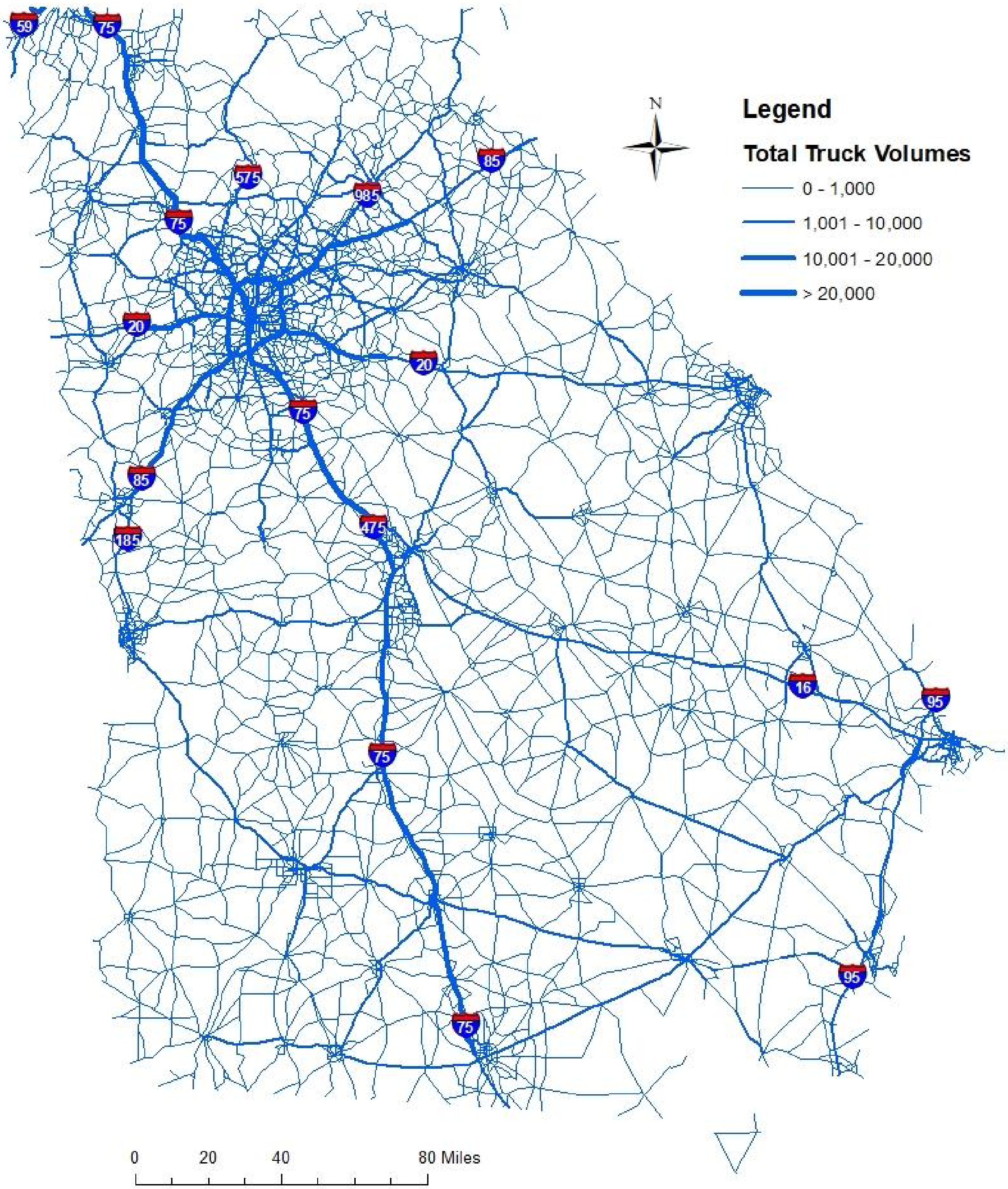


Figure 6-2: GSTDM 2015 Daily Truck Volumes

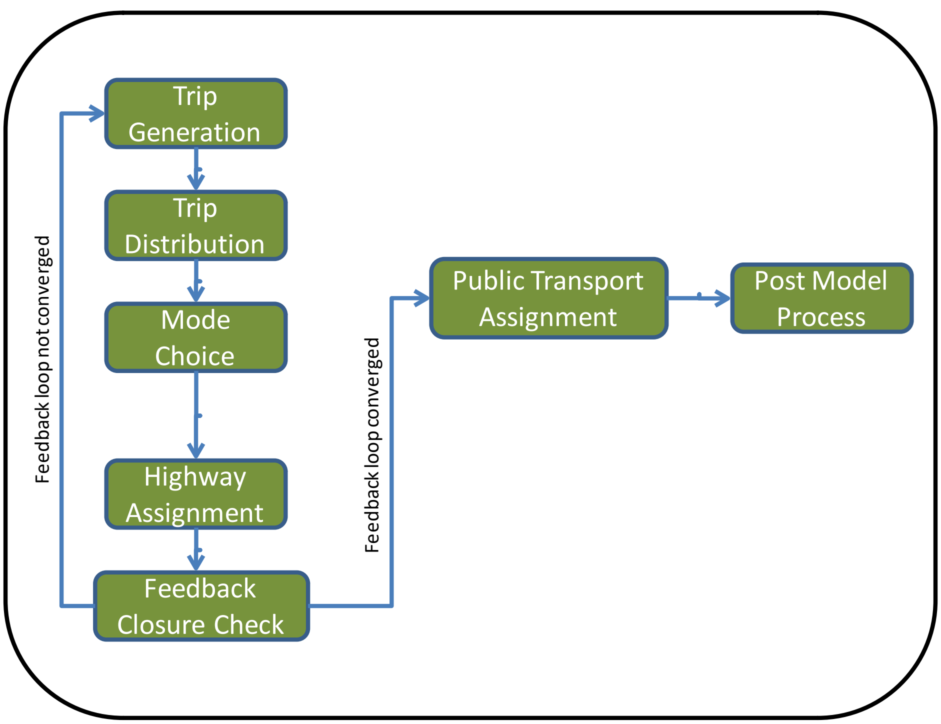


7. PASSENGER MODEL

7.1 PASSENGER MODEL PROCESS

The passenger model is another integrated part of the GSTDM. The passenger model includes both auto passenger and commercial vehicle travel. It is independent from the freight model in the trip generation, distribution and mode choice phases. The two models merge at the traffic assignment phase in which both auto passenger/commercial vehicles and trucks are loaded on the network at the same time. The purpose of this combined assignment is to account for congestion caused by both trucks and passenger cars/commercial vehicles. The passenger model also follows the traditional four-step model process with the trip generation, trip distribution, mode choice, and traffic assignment model components. In addition, a feedback loop is incorporated in the model which circles from highway assignment back to trip generation. The feedback loop takes the loaded network from the assignment and incorporates it as a new highway input network that reflect the congestion buildup in the highways. This process cycles through the passenger model until the highway link volumes from the new assignment iterations are not significantly different from the link volumes from previous assignment. This signals that the congestion in the network has reached a steady state of equilibrium and the model is ready to produce reliable results. Figure 7-1 shows the passenger model flow chart.

Figure 7-1: Passenger Model Flow Chart



The passenger model was developed based on the 2009 National Household Travel Survey (NHTS) Georgia add-on data. GDOT participated in the 2009 NHTS add-on program to obtain additional samples within Georgia. This data includes the travel patterns for the households across Georgia. It includes the household location, the work place location, the mode of transportation and travel time etc. It represents a total of almost 6,500 households with approximately 38,000 reported trips.

7.2 TRIP GENERATION

Trip generation translates the zonal socioeconomic activities into personal trips to and from a zone using predetermined trip rates. It includes two trip end components, production and attraction. The trip rates were developed from the NHTS Georgia add-on data. Because long-distance travel is an important aspect of the GSTDM, the NHTS data was analyzed by trip length in addition to the different market segments (trip purposes). Trips were divided into two categories, short and long, based on their trip length.

Trip rates for internal long-distance trips were updated based on the recommendation by the 2012 GDOT peer review. In the 2010/2040 GSTDM, the cutoff between short and long-distance trips was identified based on the travel time of 75-minutes. The peer review panel recommended the long-distance trips be defined using a distance-based threshold. The 2015/2045 GSTDM was updated using distance to identify long-distance trips. It was determined that trips longer than 50 miles in the model represent the long-distance trips. The corresponding trip rates were updated accordingly. The detailed redefinition methodology, process and results can be found in Section 7.2.2.

The updated short trips represent trips with total distance less than 50 miles which represents travel mostly within urbanized areas. The long-distance trips travel more than 50 miles and represent primarily inter-regional travel. Section 7.1.2 presents the details in developing the trip rates for long-distance and short-distance trips. The trips were also divided by the geographic ranges that define the internal and external travel. The internal travel represents trips that have both trip ends located within the state of Georgia, while the external trips have at least one leg of the trip located outside the state.

The trip purposes analyzed include home-based work (HBW), home-based other (HBO), non-home-based (NHB), as well as commercial trucks. Because the freight model already estimates long-distance truck travel, the trucks included in the passenger model are commercial trucks representing trips with a distance of less than 50 miles for the urban area trips.

The detailed definition for trip purposes used in the model is detailed as follows:

- **Home-Based Work (HBW)**: All travel made for the purpose of work and which begins or ends at the traveler's home.
- **Home-Based Other (HBO):** Any non-work trip made with one trip end at the home**.**
- **Non-Home Based (NHB):** Any trip that neither begins nor ends at home.
- **Commercial Truck:** Internal trips made by commercial vehicles.

There are many cross-border urban areas in Georgia which include Columbus to the west, Chattanooga to the north, Augusta and Savannah to the east, and Valdosta to the south. All these urban areas attract substantial cross-border trips or internal-external (IE) trips. These trips were analyzed with the trip purposes described. However, for long-distance IE trips, trips that go far beyond the adjacent border, only one general trip purpose was created due to the lack of quality data. Table 7-1 shows the organization of the trips by trip purpose and by type of geographic ranges. An aggregated total passenger vehicle trip table was used to represent external pass-through trips with both trip ends outside the state of Georgia as indicated in the table.

Table 7-1: Trip Purpose by Distance by Model

	Geographic Range	HBW	HBO	NHB	Truck
Short Distance (Urban Trips)	II	PS	PS	PS	PS
	IE	PS	PS	PS	PS
Long Distance (Intercity Trips)	II	PS	PS	PS	FT
	IE	PS (aggregated)			FT
Through Trips	EE	ME			FT

PS: Passenger model trip generation; FT: Freight model trip generation; ME: Matrix Estimation

7.2.1 Trip Production

Trip production is directly related to the households where trips originate. Thus, the trip rates for production are household based. The procedure for computing trip productions uses cross-classified data from the household stratification model which is used as a standard modeling process to calculate HBW, HBO, and NHB production trip rates. The household stratification model subdivides the total number of households in each TAZ by household size. The probability lookup tables used in the household stratification model are shown in Table 7-2.

Table 7-2: Household Stratification Lookup Table

Average Persons/HH		Estimated Probability by Household Size			
From	**To**	**1**	**2**	**3**	**4+**
0.0	1.0	1.000	0.000	0.000	0.000
1.0	1.2	0.781	0.206	0.013	0.000
1.2	1.4	0.690	0.257	0.033	0.020
1.4	1.6	0.575	0.313	0.069	0.043

Average Persons/HH		Estimated Probability by Household Size			
1.6	1.8	0.484	0.351	0.102	0.063
1.8	2.0	0.414	0.354	0.128	0.104
2.0	2.2	0.349	0.356	0.146	0.149
2.2	2.4	0.287	0.347	0.169	0.197
2.4	2.6	0.239	0.327	0.188	0.246
2.6	2.8	0.194	0.314	0.199	0.294
2.8	3.0	0.155	0.295	0.208	0.342
3.0	3.2	0.125	0.275	0.207	0.392
3.2	3.4	0.115	0.249	0.200	0.436
3.4	3.6	0.112	0.212	0.193	0.483
3.6	3.8	0.104	0.204	0.169	0.523
3.8	4.0	0.103	0.203	0.161	0.533

Data Source: CTPP 2000

The updated trip production rates were stratified into the urban versus rural, long versus short, internal versus external, low income versus non-low income, and different trip purposes. The updated trip production rates for the statewide model are shown from Table 7-3 to Table 7-6.

Table 7-3: Internal-Internal Short Trip Rates

Income	Area	Persons/HH	HBW	HBO	NHB
Low	Urban	1	0.189	1.600	0.852
		2	0.724	3.215	1.069
		3	0.644	7.943	3.383
		4	1.176	10.761	4.644
	Rural	1	0.226	1.252	1.386
		2	0.515	2.796	1.699
		3	1.106	5.874	3.425
		4	1.512	6.188	1.790
Non-Low	Urban	1	0.489	1.674	1.658
		2	0.961	3.603	2.295
		3	1.370	7.228	3.586

Income	Area	Persons/HH	HBW	HBO	NHB
		4	1.770	10.552	5.616
	Rural	1	0.494	1.525	1.503
		2	0.963	3.184	2.194
		3	1.549	6.140	3.955
		4	1.769	10.564	6.489

Data Source: 2009 NHTS Database

Table 7-4: Internal-Internal Long Trip Rates

Income	Area	Persons/HH	HBW	HBO	NHB
Low	Urban	1	0.000	0.002	0.002
		2	0.005	0.065	0.064
		3	0.048	0.121	0.091
		4	0.110	0.091	0.041
	Rural	1	0.001	0.024	0.024
		2	0.007	0.048	0.036
		3	0.070	0.043	0.008
		4	0.023	0.138	0.235
Non-Low	Urban	1	0.000	0.036	0.013
		2	0.005	0.047	0.038
		3	0.048	0.054	0.200
		4	0.110	0.128	0.167
	Rural	1	0.001	0.016	0.038
		2	0.007	0.089	0.092
		3	0.070	0.059	0.134
		4	0.023	0.286	0.416

Data Source: 2009 NHTS Database

Table 7-5: Internal-External Short Trip Rates

Income	Area	Persons/HH	HBW	HBO	NHB
Low	Urban	1	0.005	0.010	0.036
		2	0.018	0.045	0.027
		3	0.020	0.020	0.030
		4	0.026	0.179	0.103
	Rural	1	0.002	0.015	0.005
		2	0.002	0.020	0.010

Income	Area	Persons/HH	HBW	HBO	NHB
		3	0.182	0.022	0.012
		4	0.015	0.025	0.015
Non-Low	Urban	1	0.010	0.024	0.021
		2	0.038	0.065	0.033
		3	0.089	0.035	0.073
		4	0.038	0.036	0.074
	Rural	1	0.008	0.030	0.011
		2	0.007	0.042	0.024
		3	0.015	0.050	0.042
		4	0.031	0.048	0.028

Table 7-6: Internal-External Long Trip Rates

Income	Area	Persons/HH	Total
Low	Urban	1	0.008
		2	0.045
		3	0.025
		4	0.077
	Rural	1	0.045
		2	0.020
		3	0.091
		4	0.056
Non-Low	Urban	1	0.016
		2	0.046
		3	0.051
		4	0.051
	Rural	1	0.015
		2	0.035
		3	0.052
		4	0.070

Trip productions for commercial trucks are calculated using the following regression equation adopted from the GDOT MPO models.

$$P_{Commerical\ Truck} = 0.9 * Emp_{MTCUW} + 0.64 * Emp_{Retail} + 0.23 * Emp_{Service} + 0.06 * Pop$$

where $P_{Commerical\ Truck}$ is commercial truck productions, Emp_{MTCUW} is employment, Emp_{Retail} is retail employment, $Emp_{Service}$ is service employment and Pop is population.

7.2.2 Development of Long-Distance and Short-Distance Trip Rates

The 2012 Travel Model Improvement Program (TMIP) peer review of the GSTDM recommended alterations to the long-distance passenger trip definition. Specifically, the report for the peer review stated:

> The panel expressed concern that the 75-minute cutoff between short and long-distance trips may be problematic, as a time versus mileage cut-point for long-distance trips may yield knife-edge effects in the model whereby the same origin-destination set classified as "long" in some runs and "short" in others, specifically between forecast years. The panel recommended that GDOT review the National Cooperative Highway Research Program (NCHRP) 08-84 Rural and Long-Distance Travel Parameters for Statewide Models for potential application in the GSTDM and consider shifting to a distance-based criterion.[16]

Long-Distance Trip Redefinition

The NHTS Georgia add-on data were used to derive trip production rates for use in the Statewide Travel Demand Model. The existing model used a definition of trips greater than 75 minutes in travel time as 'Long-Distance Trips.' The TMIP peer review recommended using distance rather than travel time to define the long trips. Various travel models and NCHRP literature were researched by the model development team to identify reasonable metrics to be used in defining long trips. It was found that most of models in the literature used a distance-based criterion rather than a time-based criterion. Among the states that used distance-based criterion to define the long-distance trips, a slight majority of the models used a figure of 50 miles as the cutoff for long-distance trips and most of the remainder used 100 miles as the cutoff. Given the nature of travel in the state of Georgia with Atlanta being a heavily-congested area where intra-urban trips can often be longer than 75 minutes at peak times, a definition of 50 miles as long-distance trips was implemented. Table 7-7 below illustrates the comparison from (NCHRP) 08-84 - Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models (2012).

[16] *Federal Highway Administration (FHWA) Travel Model Improvement Program (TMIP). Georgia Department of Transportation (GDOT) Statewide Travel Model Peer Review Report. September 2012. Available at: https://www.fhwa.dot.gov/planning/tmip/resources/peer_review_program/gdot/gdot.pdf, p. 23.*

Table 7-7: Long-Distance Trip Thresholds by Statewide Model

State	Long-Distance Threshold		Long-Distance Trips	Total Trips	Percentage Long Distance
	In Miles	In Minutes			
Arizona	50	-	-	-	-
California	100	-	-	-	-
Florida	50	-	176,587	52,281,363	0.34%
Georgia	-	75	418,000	31,223,000	1.34%
Indiana	-	-	280,395	25,158,208	1.11%
Louisiana	100	-	75,087	11,717,965	0.64%
Massachusetts	-	-	957,046	22,951,483	4.17%
Mississippi	100	-	212,862	7,095,161	3.00%
Ohio	50	-	248,628	36,702,991	0.60%
Utah	-	-	68,866	7,131,412	0.94%
Virginia	-	100	1,071,566	37,868,443	2.83%
Wisconsin	50	-	42,966	71,313,993	0.06%

Data source: (NCHRP) 08-84 - Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models (2012), Table 4.1

Calculating and Applying New Long-Distance Trip Rates

The following methodology was used by the model development team to calculate new long-distance trip rates and apply them to the GSTDM:

- Standard database software (Microsoft Access) was used to query the Georgia 2009 NHTS database by trip distance instead of by travel time. The distance used in the query was 50 miles.
- The rates were calculated based on the number of weighted person trip records in each category divided by the weighted total households in each category.
    - The categories used were consistent with the cross classification by income (high and low), household size (1, 2, 3 and 4+) and trip purpose (Home-Based Work (HBW), Home-Based Other (HBO) and Non-Home-Based (NHB)).
- A similar query was also done using travel time (trips >= 75 minutes) for comparison purposes.

- The comparison revealed 1,333 records where trips were longer than 75 minutes and 1,407 records where trips are longer than 50 miles.

- A query was also done to identify the number of records that were not common to the distance and travel time queries. That comparison revealed 416 such records. These records represent the instances where trip distance and trip time are not directly correlated such as during congested conditions.

- The new rates were applied to the model trip generation script and the resulting trip generation output was compared to the generation output from the existing rates.

Rates

Table 7-8 below illustrates the existing long trip rates in the model while Table 7-9 illustrates the newly calculated rates using the 50-mile distance cutoff.

Table 7-8: Existing Rates (Based on 75-Minute Travel Time Cutoff)

Income	Area	Persons per / Household	HBW	HBO	NHB
Low (<$20,000 per year)	Urban	1	0.001	0.036	0.005
		2	0.002	0.063	0.009
		3	0.003	0.083	0.020
		4	0.005	0.060	0.154
	Rural	1	0.045	0.016	0.010
		2	0.043	0.087	0.130
		3	0.003	0.045	0.040
		4	0.167	0.667	0.056
Non-Low (>= $20,000 per year)	Urban	1	0.003	0.013	0.010
		2	0.005	0.041	0.017
		3	0.009	0.041	0.054
		4	0.015	0.127	0.036
	Rural	1	0.002	0.032	0.021
		2	0.022	0.104	0.042
		3	0.007	0.095	0.087
		4	0.022	0.081	0.059

Table 7-9: Derived Rates (Using No Income Stratification for HBW and 50 Mile Cutoff)

Income	Area	Persons per / Household	HBW	HBO	NHB
Low (<$20,000 per year)	Urban	1	0.000	0.002	0.002
		2	0.005	0.065	0.064
		3	0.048	0.121	0.091
		4	0.110	0.091	0.041
	Rural	1	0.001	0.024	0.024
		2	0.007	0.048	0.036
		3	0.070	0.043	0.008
		4	0.023	0.138	0.235
Non-Low (>= $20,000 per year)	Urban	1	0.000	0.036	0.013
		2	0.005	0.047	0.038
		3	0.048	0.054	0.200
		4	0.110	0.128	0.167
	Rural	1	0.001	0.016	0.038
		2	0.007	0.089	0.092
		3	0.070	0.059	0.134
		4	0.023	0.286	0.416

Results

All scripts and travel model files with the new long-distance rates are included with this memo. Table 7-10 below illustrates the trip generation results from the old and new rates respectively. The table header definitions are given as follows:

- GAL_PHBW – Long-Distance Georgia Home-Base Work trips.
- GAL_PHBO – Long-Distance Georgia Home-Based Other trips.
- GAL_PNHB – Long-Distance Georgia Non-Home-Based trips.

Table 7-10: Long-Distance I-I Trip Generation Results

	GAL_PHBW	GAL_PHBO	GAL_PNHB	Total
Total Trips (75 Minute Cutoff)	16,789	112,115	56,759	185,663
Total Trips (50 Mile Cutoff)	66,702	134,088	190,433	391,223

Calculating and Applying New Short-Distance Trip Rates

Given the results of the application of new long-distance trip rates based on a 50-mile distance threshold, it became apparent that, for consistency, a similar exercise should be undertaken for short distances (trips less than 50 miles in distance). The same methodology as applied for the long-distance rates was applied to the calculation of the short-distance rates with the exception that the distance criteria was shifted from trips at least 50 miles in length to trips less than 50 miles. A model run was then undertaken with modified long and short-distance rates and the results summarized. Table 7-11 below illustrates the trip generation results from the old long and short-distance rates and the new rates respectively.

Table 7-11: 2010 Base Year I-I Trip Generation Results (All Short-Distance Trips)

	Home-Based Work Trips	Home-Based-Other Trips	Non-Home-Based Trips	Total
Total Trips (<75 Minute Cutoff)	3,388,411	16,776,214	8,935,964	29,100,589
Total Trips (<50 Mile Cutoff)	4,092,104	20,231,042	11,790,872	36,114,018

As was the case for the long-distance revision, the overall assigned short-distance trips increased by approximately 7,000,000 statewide when using the new threshold. Figure 7-2 and Figure 7-3 below graphically illustrate the impact.

Figure 7-2: 2010 Base Year Assignment Flows Using 75-Minute Threshold

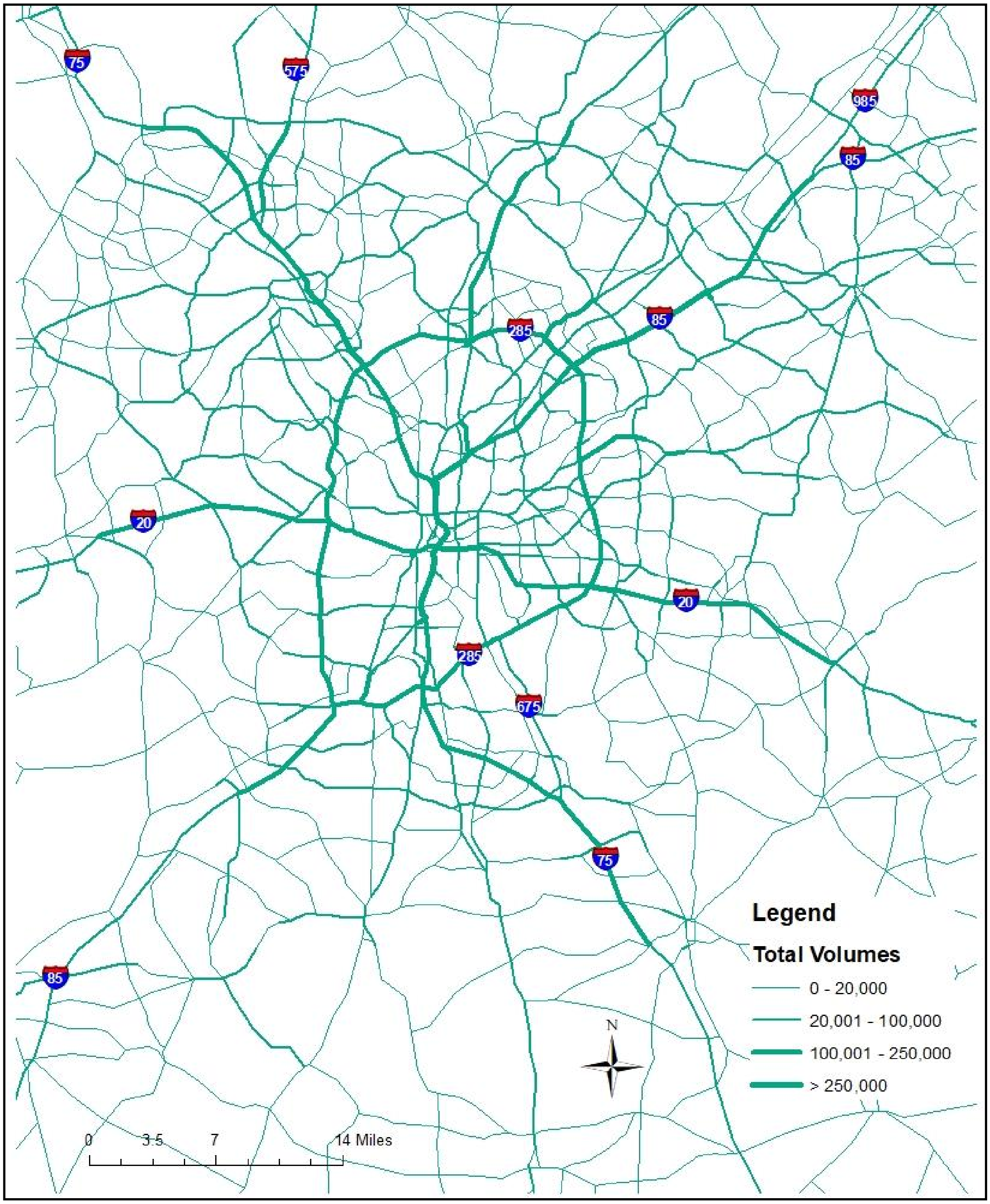


Figure 7-3: 2010 Base Year Assignment Flows Using 50-Mile Threshold

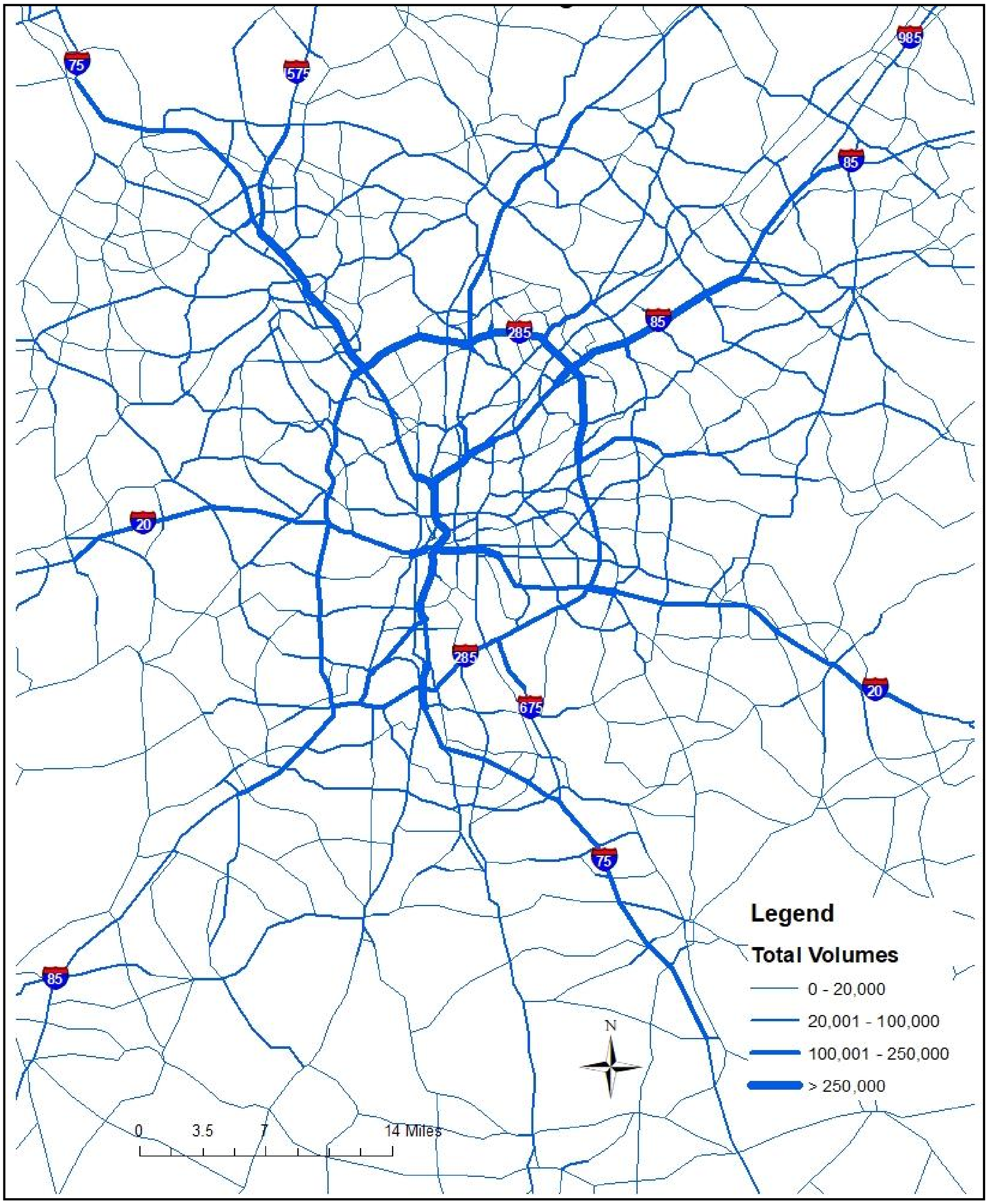


Table 7-12 illustrates the VMT effects using the new rates.

Table 7-12: 2010 VMT Comparison

HPMS Functional Class	Description	Existing Rates (75 minute Cutoff)	New Rates (50 Mile Cutoff)	Percent Change
1	Interstate	79,606,938	96,200,950	20.8%
2	Other Freeways and Expressways	6,755,026	7,737,834	14.5%
3	Principal Arterial	48,249,404	56,918,133	18.0%
4	Minor Arterial	41,908,253	50,161,152	19.7%
5	Major Collector	13,254,607	16,248,973	22.6%
6	Minor Collector	803,629	990,307	23.2%
7	Local	369,330	480,003	30.0%
	All	**190,947,187**	**228,737,352**	**19.8%**

As can be seen from the tables referenced above, the new rates result in higher trip generation numbers when compared to the original rates.

7.2.3 Trip Attraction

Unlike the trip production procedure which is household based, the trip attraction routine estimates the number of trips attracted to each TAZ based on employment. Using the reconciled socioeconomic data and the NHTS add-on survey, the following regression equations were updated for trip attractions by purpose for the 2015/2050 GSTDM. As per guidance from 1996 *Quick Response Freight Manual* (QRFM), the commercial truck attractions are equal set to productions.

$$HBW = 1 \times Emp_{Total}$$

$$HBO = 5.3 * Emp_{Retail} + 1.5 * Emp_{Service} + 0.5 * Emp_{NonRet,NonServ} + 0.95 * HH$$

$$NHB = 0.4 * Pop + 2.9 * \left(Emp_{Retail} + Emp_{MTCUW}\right) + 0.55 * Emp_{Service}$$

Commercial Truck = Commercial Truck Production

where HBW, HBO, and NHB are attractions by purpose, EmpTotal is total employment, Emp_{MTCUW} is employment, Emp_{Retail} is retail employment, $Emp_{Service}$ is service employment, $Emp_{NonRet,NonServ}$ is non retail and non-service employment, HH is households, and Pop is population.

The trip attraction rates are less reliable than the household-based production rates because employment data is more dynamic than household data. Eventually, all trip productions have to be linked with associated trip attractions to complete a trip. Therefore, the trip attractions were subsequently scaled to match the total productions in the model.

7.2.4 Trip Density Measure

Travel patterns vary by regions in Georgia due to different local economic conditions, existing transportation infrastructure, and demographic composition. Since all of these factors significantly influence trip decision makings and frequency, adjustments to the trip rates were deemed necessary to reflect these differences and to facilitate the model calibration. A trip density, or accessibility, measure was introduced in the trip generation process to account for these varying situations. The trip density measures the level of convenience for individuals to reach major employment and population centers. The level of the convenience indirectly influences the frequency in trip making. For each zone (i), the trip density measure was calculated using the following equation:

$$Trip\ Density\ Measure = \frac{\left(Pop\ (j) + Emp_{Total}(j)\right)}{\left(Time_{Congested}\right)^2}$$

where: numerator is a measure of activity in zone (j), and denominator is the impedance in terms of travel time

For example, the more accessible an area is, the more likely people will make short trips to access jobs and goods and services in the area. This is the general case for the urbanized areas where people tend to have most of their activities within their convenient reach. On the other hand, there is less incentive for people to make long trips to access these same activities outside the area. This is reflected in the equation where the employment and population are the proxies for activities and travel time is the proxy for convenience. The density measure thus depends on the land use as well as the transportation network. As the land use pattern and transportation network change, the trip density measure will respond to the changes accordingly. The potential induced travel as a result of this change can be captured by the model especially for future alternative analysis. The trip density measure produces an index number which is then scaled and applied to the trip rates to make the adjustment that reflects the level of accessibility. This adjustment is made to the existing trip rates but is not the main driver for the trip rate. The index thus is scaled to adjust the original trip rate within 1 standard deviation. The trip density measure by trip type is illustrated in Figure 7-4. As the figure shows, the higher the density measure the better the level of accessibility. The measure was applied to the production and attraction rates to reflect the difference in accessibility.

The total person trips calculated from the trip generation by trip purpose and by geographic range is shown in Table 7-13. The EE trips were developed separately from matrix estimation and were not created as a part of the trip generation.

Figure 7-4: Trip Density Measure

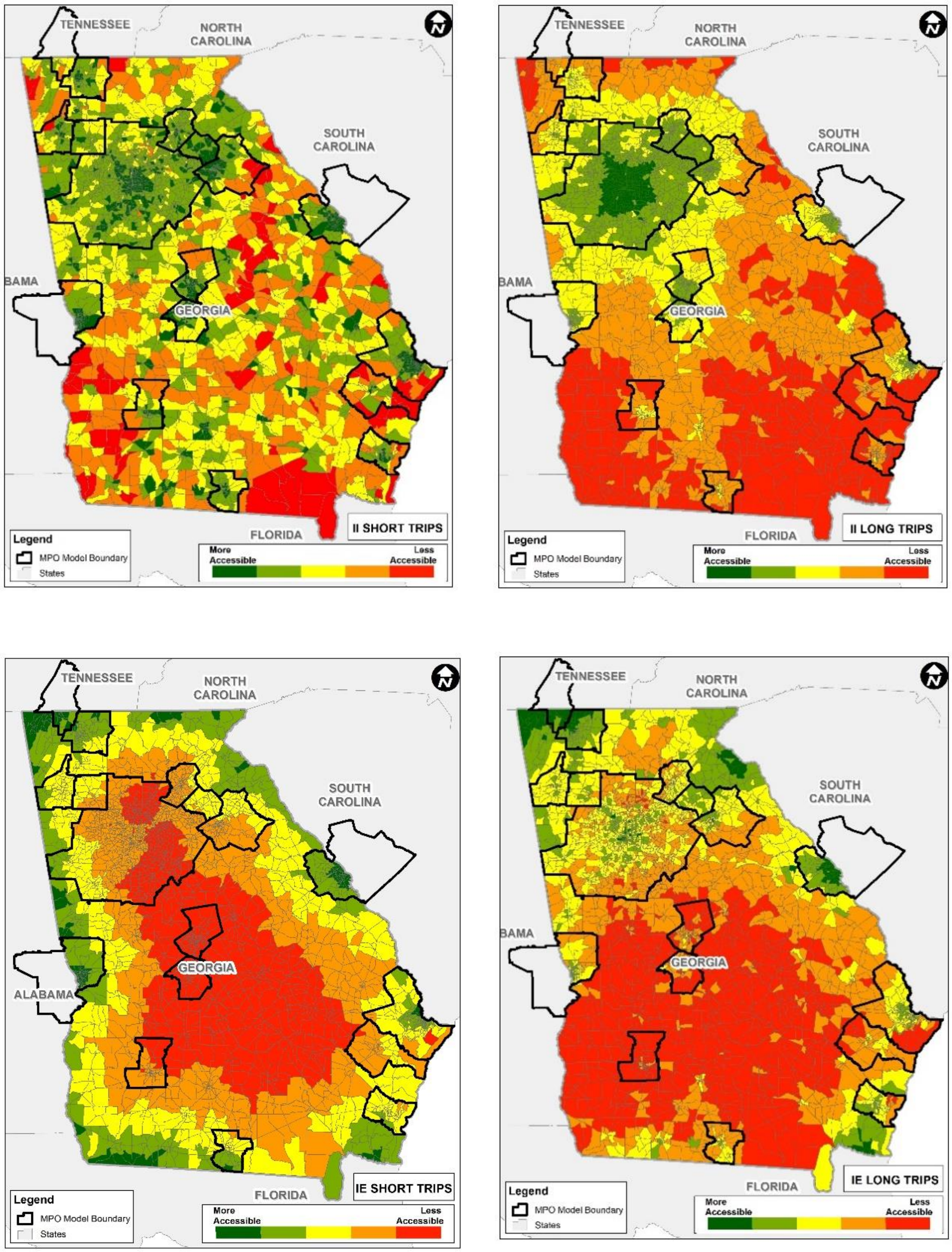


Table 7-13: 2010 Base Year Passenger Model Trips (in thousands)

	Flow Movement	HBW	HBO	NHB	Total Person Trips	Truck Trips
Short Distance (Urban Trips)	II	4,147	16,920	9,263	30,331	1,982
	IE	60	58	58	176	18
Long Distance (Intercity Trips)	II	70	113	153	335	NA
	IE	69	92	76	237	NA
Total Trips		4,346	17,184	9,549	31,079	1,999

7.3 TRIP DISTRIBUTION

The trip distribution uses the traditional gravity model process. The estimated number of person trips travelling between any O-D pair will, in general, be proportional to the number of trip ends (mass) and inversely proportional to the travel time(distance?). The trip ends are the productions and attractions calculated from the trip generation step. The travel time reflects the minimum time for trips traversing between each O-D pair in a congested highway condition. Intrazonal travel time is the travel time for trips with both origin and destination within a zone. Intrazonal trips are very short trips that do not have an impact on the highway congestion. The amount of the intrazonal trips is determined by the size of the zones and the intrazonal travel time is calculated from the travel time to nearest zones. Terminal times were assigned between O-D pairs and were based on the employment density of the origin and destination TAZ's. At the trip origin, terminal time generally refers to the walk time from one's residence to the car. At the destination end, it generally represents the time it takes to go from one's car to the destination. Depending on the characteristics of the zone, terminal time can vary. The following terminal time were used in the model to reflect the different area types.

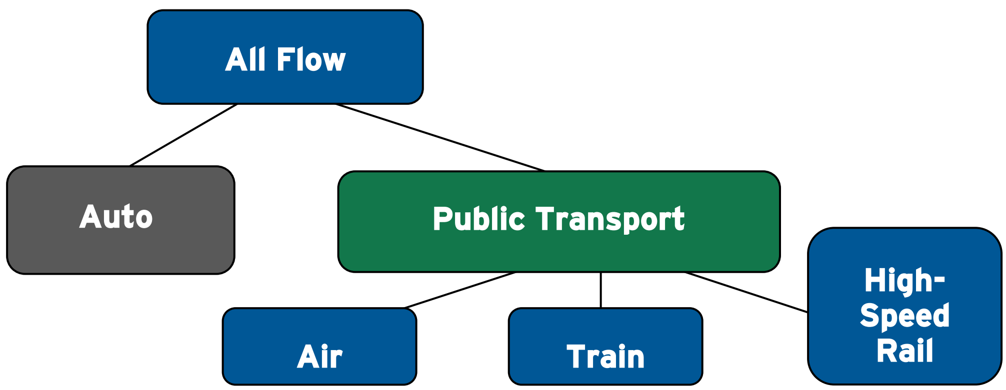
- Urbanized area: 5 min
- Suburban area: 3 min
- Rural area: 1 min

The total travel time between each O-D pair is converted into travel time impedance factors or friction factors. These factors along with production and attraction trip ends are the inputs to the gravity model which links the trip ends into complete trips. During the process of converting the trip ends into completed trips, the gravity model was validated against the distribution patterns observed. These include the average travel time as well as the trip length frequency distribution. The NHTS add-on data was geo-coded by trip origin and destination and survey trip tables were developed to facilitate the gravity model validation. The trip distribution pattern estimated from the gravity model was then compared against that from the 2009 NHTS data. The gravity model was calibrated by adjusting the friction factors until the resulting distribution pattern sufficiently replicates the NHTS. See Chapter 8 for passenger trip distribution validation results.

7.4 MODE CHOICE

The mode choice process determines what mode of travel will be used to complete the passenger trips between zones. The alternative modes considered in the statewide model are autos, inter-city train, high-speed rail, and air. The model structure is shown below.

Figure 7-5: Passenger Mode Choice Model Structure



The mode choice model was applied to trips with both trip ends located within Georgia or external trips with the external trip end located in the surrounding region. Long-distance external trips between Georgia and regions far beyond were not included. The mode choice for this type of trip uses a simple mode split with fixed auto passengers share by distance shown in Table 7-14. These shares were developed from the 2009 NHTS.

Table 7-14: IE Long-Distance Trips Mode Split

Distance Range (miles)	< 500	500-750	750-1000	1000-1500	>1500
Auto Share	95%	62%	42%	32%	15%

Data Source: 2009 NHTS

A mode choice model usually requires a well-designed survey built specifically to inform the model development. Unfortunately, the 2009 NHTS add-on data for Georgia did not have sufficient observations to develop and/or update a complete mode choice model. The model therefore was borrowed from another similar model, the “Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study” which includes the mode for air, trains, and high-speed rail. The model coefficient was then adjusted to produce results that reasonably match the overall mode shares observed in Federal Aviation Administration (FAA) airport boarding data, Amtrak boarding data, and 1995 American Travel Survey data for long-distance travel for Georgia. Due to the limitations of the data, it is recommended that the mode choice model be used with caution for the rail and air components. It should be used to estimate general modal trends and not be used to produce detailed absolute ridership.

The variable coefficients for the logit choice model are shown in Table 7-15. These coefficients were applied to each of the input variables to calculate the utility value for each of the modes. Passenger trips were categorized as work related and non-work related. These trips belong either to HBW trip or non-work-based trip types in the statewide model. The costs reflect the real monetary measure of fees for transportation. The air fare is the 2015 market fare from the FFA origin and destination survey. The fare for the train is the average dollar amount per mile at current market price which is $0.35/mile. In-vehicle time is the time spent in the selected mode of transportation. The values are obtained by skimming the network associated with the different mode. Out-of-vehicle time is the time used to travel from origin zone to the zones with designated boarding facilities for specific mode. These facilities can be train stations or airports. No out-of-vehicle time is assigned to highway travel. Headway was defined as the number of flights or trains available per day. Reliability reflects the possibility of delay caused by external factors. The reliability is estimated as 70 percent for air travel, 98 percent for train, and 90 percent for auto.

Table 7-15: Logit Choice Model Coefficients excluding Constants

Trip Type	Costs	In-Vehicle Time	Out-of-Vehicle	Headway	Reliability	Household size
Work/Business	-0.016	-0.016	-0.060	-0.003	0.001	0.070
Non-Work/Business	-0.035	-0.011	-0.030	-0.003	0.005	0.225

Data Source: Bay Area/California High-Speed Rail

Due to the limitation of the zone sizes and the lack of mode data, there are restrictions applied to the mode choice model. For example, for the air mode, only direct flight services within Georgia were considered, and trips with a distance less than 100 miles were excluded. This is because there is not sufficient data available to model flight transfers and trips less than 100 miles are unlikely to use the air mode. In addition, unlike highway travel, airlines operate using a hub and spoke system. In the southeastern US, Atlanta is a major hub for several airlines. Figure 7-6 displays the hub and spoke system that links Atlanta to other hubs or regional airports included in the model. A listing of the variables in the airline network is listed in Appendix E.

The conventional train mode mainly represents Amtrak service. Currently, there are four major services running through Georgia, with one serving Atlanta and the other three connecting Savannah to rest of the regions. The four services are Crescent, Silver Star, Silver Meteor and Palmetto. Figure 7-7 shows the Amtrak routes and the stops along the routes. As the figure shows, the train mode only includes passenger travel that must have a trip end within Georgia. External pass through trips are not considered by the mode choice model due to the limitations discussed earlier. In addition, as the train is used primarily for medium to long-distance travel, trips less than 50 miles are not considered in the model. Rail fares were adjusted as part of the 2015/2050 GSTDM update.

Figure 7-6: Modeled Airports

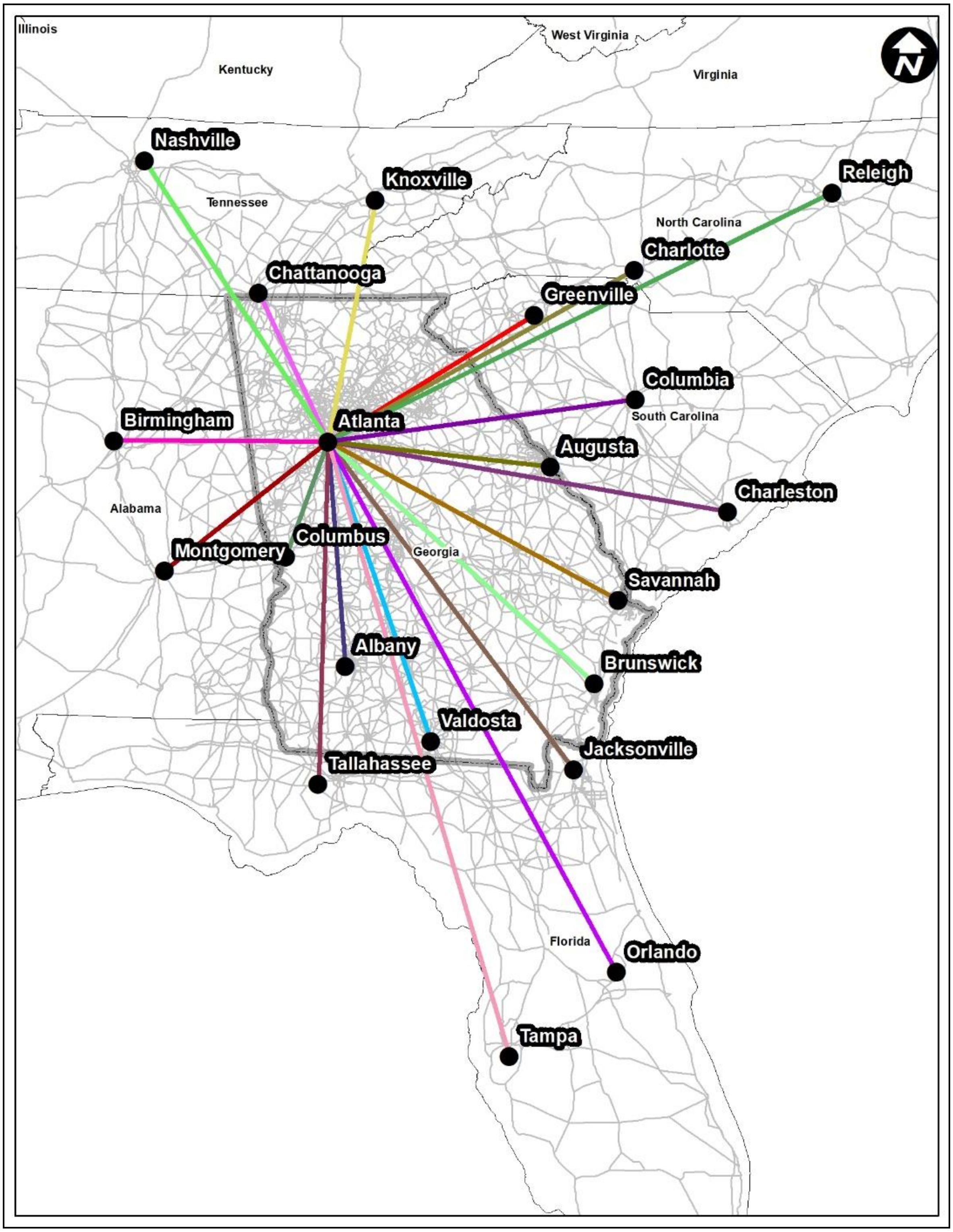
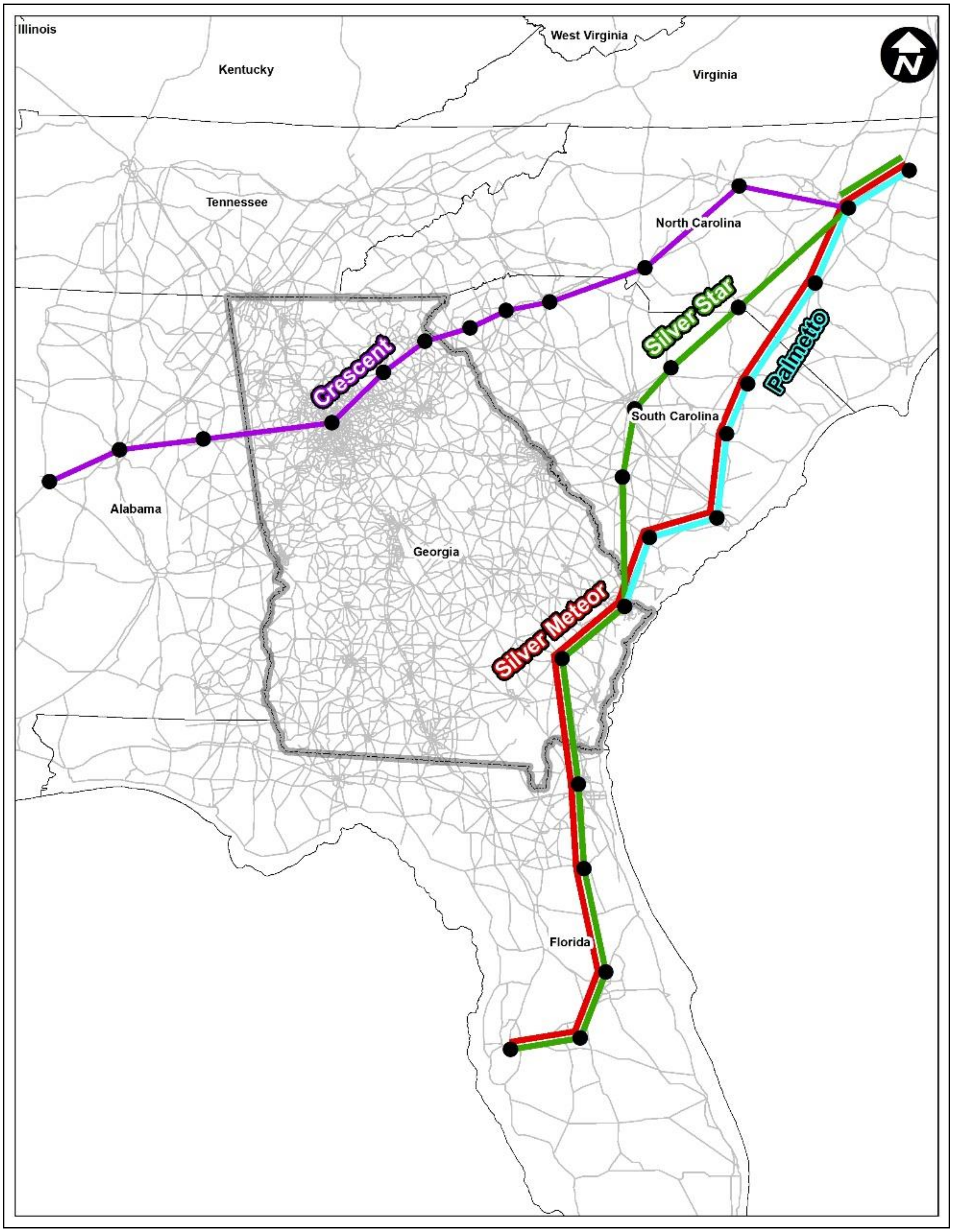


Figure 7-7: Amtrak Passenger Rail Routes



7.5 ASSIGNMENT

The last step in the modeling sequence is the assignment of the trip tables to logical routes in the transportation network. Highway trip assignment is performed using the equilibrium assignment technique. The traffic assignment algorithm is iterative, running through successive applications until equilibrium occurs. Equilibrium occurs when no trip can take an alternate path without increasing the overall travel costs of all other trips in the network. The equilibrium assignment is an iterative process that simulates travel demand along the minimum time paths as well as the effects of accumulated congestion. In each iteration, vehicles are loaded onto network links and the links' travel impedances are adjusted in response to the volumes to capacity relationships. Final link volumes are derived by summing weighted average volumes from the all iterative loadings. The travel impedances are generalized costs which include link travel time as well as vehicle operating costs. Values of time for the passenger and freight truck assignment are $15/hour and $60/hour, respectively. The vehicle operating costs for auto passenger car and freight truck are $0.12/mile and $0.50/mile, respectively. Peak and off-peak impedances are defined. The peak impedance reflects congested conditions where all network links are loaded with estimated amount of traffic. The off-peak impedance is the weighted average of congested and free flow conditions. The peak impedance is primarily used for the short trips, mostly commute trips within urbanized areas where travel is sensitive to local congestion levels. The off-peak impedance is used for longer trips which are less sensitive to localized traffic congestion. These trips include intercity passenger trips and long-haul freight trucks.

The assignment attaches additional network link attributes to the input network to store the results. These additional attributes provide volumes, travel time, speed, and so on which can be used to summarize network-wide link statistics. A list of these added attributes is shown in Table 7-16 below.

Table 7-16: GSTDM Output Network Attributes

Attribute Name	Description
TAZ	Nearest TAZaz ID
AREATYPE	Area Type
FTYPE	Facility Type
SPEED	Free flow Speed in Mile per Hour (Miles per Hour)
TIME_FF	Free Flow Travel Time (Minutes)
CAPACITY	Daily Capacity (Vehicles per Day)
TIME_1	Congested Link Travel Time (Minutes)
CSPD_1	Congested Speed (Miles per Hour)
EEPC	Georgia Through Passenger Daily Vehicle Volumes

Attribute Name	Description
PC_V	Passenger Daily Vehicle Volumes
PC_VT	Passenger Daily Vehicle Volumes (Two-way)
GA_NEAR	Internal Passenger Short Trips
GA_LONG	Internal Passenger Long Trips
IE_NEAR	Internal-External Passenger Short Trips
IE_LONG	Internal-External Passenger Long Trips
FRGHT_V	Freight Daily Vehicle Volumes
FRGHT_VT	Freight Daily Vehicle Volumes (Two-way)
EEFRGHT	Georgia Through Fright Daily Vehicle Volumes
EE	Georgia Through Daily Vehicle Volumes
TOTAL_V	Total Daily Vehicle Volumes
TOTAL_VT	Total Daily Vehicle Volumes (Two-way)
VC	Daily Volume over Capacity Ratio
VMT	Total Daily Vehicle Mile of Travel
VHT	Total Daily Vehicle Hour of Travel
FRGHT_VMT	Total Daily Freight Vehicle Mile of Travel
FRGHT_VHT	Total Daily Freight Vehicle Hour of Travel

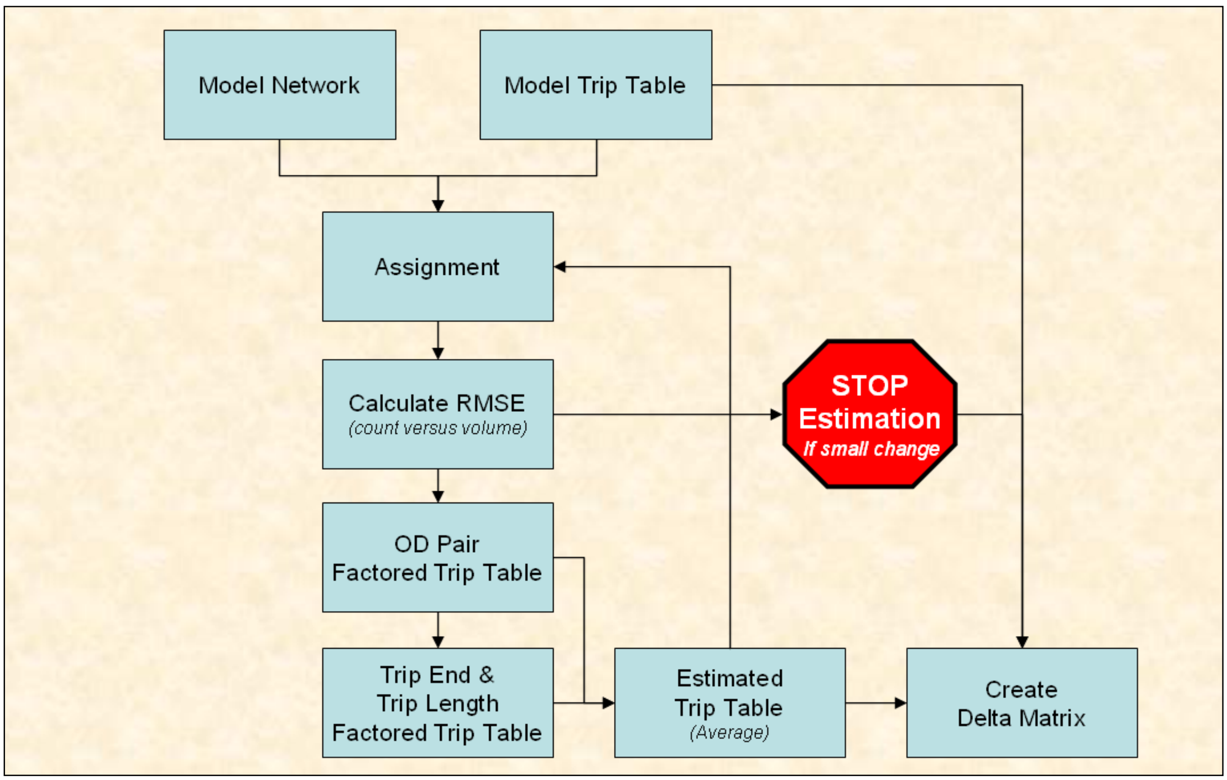
7.6 DELTA MATRIX PROCESS

Due to the many variables involved, estimated traffic volumes from travel demand models will inevitably differ from observed traffic counts. As a result, it is usually necessary to post-process modeled volumes for use in traffic studies. National Cooperative Highway Research Program (NCHRP) Report 255 outlines a widely used methodology for post-processing model results, but like many approaches to refining travel demand models, the procedures are intended for specific projects or corridors and are not easily applied to an entire region.

Matrix estimation techniques to post-process travel demand model volumes for an entire state have been developed for the Georgia Statewide Model. This statewide level post-processing is done by developing a delta matrix, which is a trip table that is combined with the normal travel demand model trip table to produce traffic assignments that closely replicate observed traffic counts.

Figure 7-8 outlines how a delta matrix is developed. The delta matrix process uses the travel demand model trip table as a seed for a matrix estimation process. The matrix estimation process attempts to closely replicate observed traffic counts, while also controlling the trip ends and trip lengths possessed by the seed matrix. This is accomplished by iteratively assigning a trip table, adjusting the trip table to match traffic counts, then applying a tri-proportional fitting process to match trip ends and trip lengths. Once a trip table is produced that sufficiently matches the traffic counts, a delta matrix is produced by subtracting the initial seed trip table from the estimated trip table.

Figure 7-8: Delta Matrix Process



Conceptually the resulting delta matrix represents the localized factors that the regional travel demand modeling process does not reproduce well. Future travel demands are post-processed by applying the same local corrections that are represented in the delta matrix without adjustment since similar localized issues cannot be identified for future conditions. Therefore, the delta matrix is simply added to future trip tables before assigning the trips.

8. MODEL VALIDATION

Model validation is defined as the process by which the base year model results are compared to actual, observed travel pattern data. It is a regular and essential process including refining the model parameters until the model reasonably replicated the base year travel patterns for both passenger and freight. The 2015 GSTDM model was checked for accuracy by reviewing the model inputs and outputs under each of the major steps in the TDM process starting from trip generation to trip assignment. Specific efforts include reviewing transportation network and attributes, trip generation and distribution parameters, average trip length by purpose, vehicle-miles traveled comparison, volume to count comparison and statistics at several levels – statewide, regional, corridor (including screenlines) and at link level. Validation details and results are presented in the following sections.

8.1 TRIP GENERATION

The trip rates were validated against the experience from peer statewide models as well as the NHTS add-on data. Table 8-1 presents a summary of aggregated trip rates identified in the passenger trip model along with the range observed in peer statewide models. There is a wide range in trip rates among the statewide models due to the size of zones, population, and employment, as well as length of trip modeled. However, the aggregated passenger model trip rates are reasonably within the range of other statewide models' experience.

Table 8-1: Aggregated Trip Rates Summary

	GSTDM	NCHRP Range
Person Trips/TAZ	10,149	2,134~16,197
Person Trips/Person	3.29	1.95~4.24
Person Trips/Household	9.21	5.41~10.33
Person Trips/Employee	8.19	4.41~8.76

** Values from Validation and Sensitivity Considerations for Statewide Model NCHRP Project 836-B Task 91, September 2010*

Table 8-2 shows the comparison between the model results and the 2009 Georgia NHTS add-on data. The passenger model's trip rates are within a close approximation to the NHTS add-on data.

Table 8-2: Trip Rates Comparison

	GSTDM	2009 NHTS Add-on
Person Trips/Household	9.21	7.80
Person Trips/Person	3.29	3.20
% HBW Trips	13%	13%
HBW Trips/Household	1.19	1.00
HBO Trips/Household	4.78	4.50
NHB Trips/Household	2.65	2.30

Data Source: 2009 Georgia NHTS Add-on data

8.2 TRIP DISTRIBUTION

The gravity model was validated against the distribution patterns observed. This included the comparison of average travel time by trip type. Table 8-3 presents average values for trip length by purpose, internal/external flows, and long and short distance. Target average travel times were obtained from the NHTS 2009 add-on data.

The gravity model for short trips produces better results in matching the trip distribution pattern than the longer trips. The mismatch of long-distance and external trips between the gravity model and the NHTS survey is due to insufficient data for longer distance travel in the NHTS survey. Additional data for those trip types would help improve the comparison for the long and external trip types.

Table 8-3: Average Trip Length (Minutes)

	Target	Model
II HBW Short Trips	26	27
II HBO Short Trips	20	22
II NHB Short Trip	18	20
II HBW Long Trips	118	138
II HBO Long Trips	142	140
II NHB Long Trips	127	122
IE HBW Short Trips	37	40
IE HBO Short Trips	35	37
IE NHB Short Trips	33	34

Data Source: 2009 Georgia NHTS Add-on Data

Statewide models cover much larger areas and produce more long trips than MPO models and include cross-regional trips that are typically modeled as external trips in MPO models. The average trip length in the statewide models is clearly longer than those in the MPO models. Thus, the average travel time can vary greatly depending on the size of the modeled area. The average travel time from the gravity model was thus compared with the experience from other statewide models to check the model's reasonableness. Table 8-4 summarizes the average trip lengths for short trips and the comparison between those found in other peer statewide models and surveys. Because the definition for long-distance trips can be widely different, this comparison only focuses on the short trips defined in the GSTDM. The average trip lengths from the model are within a reasonable range when compared to the other peer statewide models.

Table 8-4: GSTDM Short-Distance Trip Average Length Comparison (Minutes)

Trip Purpose	Statewide Model	2009 Georgia NHTS Add-on	Other Statewide Models*		Travel Survey		NCHRP	
			Low	High	Low	High	Low	High
HBW	27	26	11	23	16	24	11	35
HBO	22	20	9	19	14	16	10	17
NHB	20	18	9	23	13	23	9	19

Note: ** Values from Validation and Sensitivity Considerations for Statewide Model, NCHRP Project 836-B Task 91, September 2010*

The best way to measure the travel pattern resulting from major trip movement across the region is to perform a district to district flow analysis. This provides a clear view on how well the gravity model allocates trips on an aggregated level compared with the existing condition. Based on the availability of data, this comparison was possible only for the work trips (HBW purpose). Similar to the freight gravity model validation, the 12 districts based on the Georgia Regional Commissions were used. To facilitate the validation effort, the cross-region work flows from the Census' 2009-2013 five-year American Community Survey (ACS) were also developed according to these districts. The comparison therefore was made between the gravity model and ACS data. Table 8-5 and Table 8-6 show the comparison of district to district work trips between the HBW trip from the Gravity model and the ACS survey while Figure 8-1 graphically shows the comparison. It is expected that there will be some discrepancies in the comparison since both the model and survey data contain certain levels of inaccuracy. The model generally matches the survey reasonably well.

Table 8-5: District to District Work Flow - GSTDM

	NW GA	GA Mountains	Three Rivers	NE GA	Mid GA	Ctr. Savh River	River Valley	Heart of GA	SW GA	S GA	Coast al	ARC	Total Model
NW GA	287,826	2,535	3,808	44	171	1	5	2	7	465	639	25,489	320,992
GA Mountains	2,537	197,862	15	7,736	11	15	5	2	4	1	55	30,232	238,475
Three Rivers	3,807	15	143,622	1,105	2,417	115	4,854	3	25	2	8	23,901	179,874
NE GA	44	7,749	1,105	149,217	2,366	651	5	4	4	2	13	31,224	192,384
Mid GA	170	11	2,414	2,362	172,142	838	2,189	2,995	98	108	154	1,569	185,050
Ctr. Savh River	1	19	115	648	839	165,342	159	1,474	13	13	1,827	817	171,267
River Valley	4	4	4,856	4	2,186	159	119,595	621	2,379	2,126	11	653	132,598
Heart of GA	2	2	3	4	2,992	1,474	621	95,337	111	3,291	4,781	377	108,995
SW GA	7	4	25	4	96	13	2,384	111	129,279	7,006	87	669	139,685
S GA	464	-	2	2	94	13	2,116	3,289	6,969	134,883	1,740	214	149,786
Coastal	639	55	7	12	146	1,837	11	4,779	89	1,774	255,869	849	266,067
ARC	25,588	30,281	23,962	31,208	1,643	919	766	397	711	289	901	1,611,847	1,728,512

Notes: NW GA – Northwest Georgia Regional Commission; GA Mountains – Georgia Mountains Regional Commission; Three Rivers – Three Rivers Regional Commission; NE GA – Northeast Georgia Regional Commission; Ctr. Savh River – Central Savannah River Regional Commission; River Valley – River Valley Regional Commission; Heart of GA – Heart of Georgia Regional Commission; SW GA – Southwest Georgia Regional Commission; S GA – South Georgia Regional Commission; Coastal – Coastal Regional Commission; ARC – Atlanta Regional Commission.

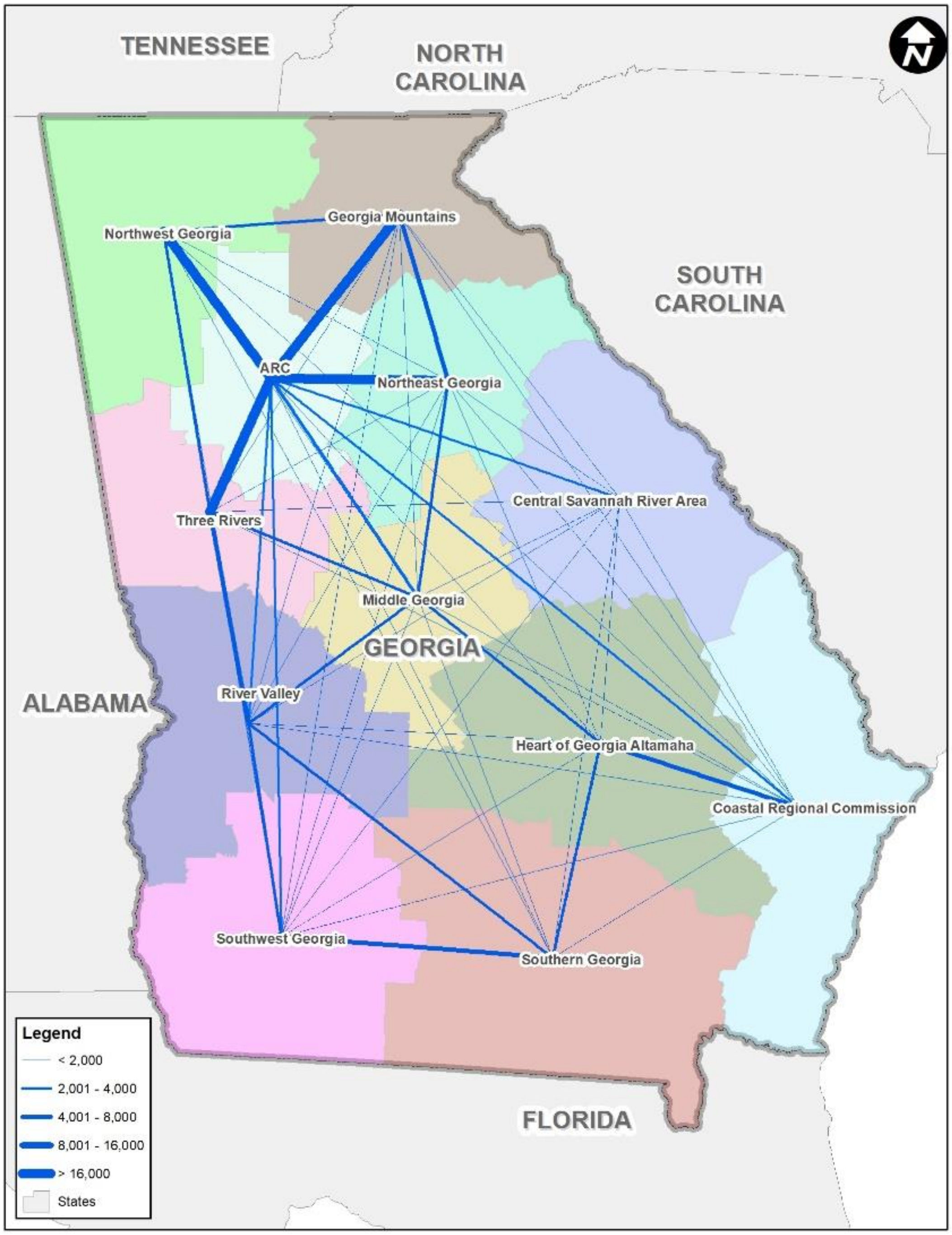
Table 8-6: District to District Work Flow - ACS

RC	NW GA	GA Mountains	Three Rivers	NE GA	Mid GA	Ctr. Savh River	River Valley	Heart of GA	SW GA	S GA	Coastal	ARC	2015 Observed
NW GA	247,296	1,865	4,575	330	147	211	210	29	25	30	46	65,477	320,241
GA Mountains	1,410	188,544	184	8,194	310	236	76	18	70	22	213	59,920	259,197
Three Rivers	3,618	416	128,697	893	2,360	85	2,253	0	272	133	105	57,835	196,667
NE GA	437	9,672	977	165,855	1,862	818	98	76	80	15	62	62,317	242,269
Mid GA	141	55	966	2,406	183,985	761	1,084	1,261	90	183	636	3,691	195,259
Ctr. Savh River	26	57	8	1,237	1,714	165,412	75	1.217	17	38	956	1,065	171,822
River Valley	43	75	3,741	30	3,576	44	133,273	287	2,203	217	136	1,159	144,784
Heart of GA	18	13	85	68	4,714	1,743	583	86,630	61	1,929	7,083	416	103,343
SW GA	12	5	68	45	147	23	1,696	77	119,942	3,995	108	292	126,410
S GA	93	98	132	0	367	139	656	1,298	2,761	139,440	4,329	568	149,881
Coastal	156	67	53	56	110	485	182	4,111	75	838	272,075	889	279,097
ARC	14,980	31,569	15,508	18,526	2,987	1,032	1,916	445	547	456	761	1,813,764	1,902,491
Total Observed	268,230	232,436	154.994	197,640	202,279	170,989	142,102	95,449	126,143	147,296	286,510	2,067,393	4,091,461

Data Source: 2009-2013 Five-Year American Community Survey (ACS)

Notes: NW GA – Northwest Georgia Regional Commission; GA Mountains – Georgia Mountains Regional Commission; Three Rivers – Three Rivers Regional Commission; NE GA – Northeast Georgia Regional Commission; Ctr. Savh River – Central Savannah River Regional Commission; River Valley – River Valley Regional Commission; Heart of GA – Heart of Georgia Regional Commission; SW GA – Southwest Georgia Regional Commission; S GA – South Georgia Regional Commission; Coastal – Coastal Regional Commission; ARC – Atlanta Regional Commission.

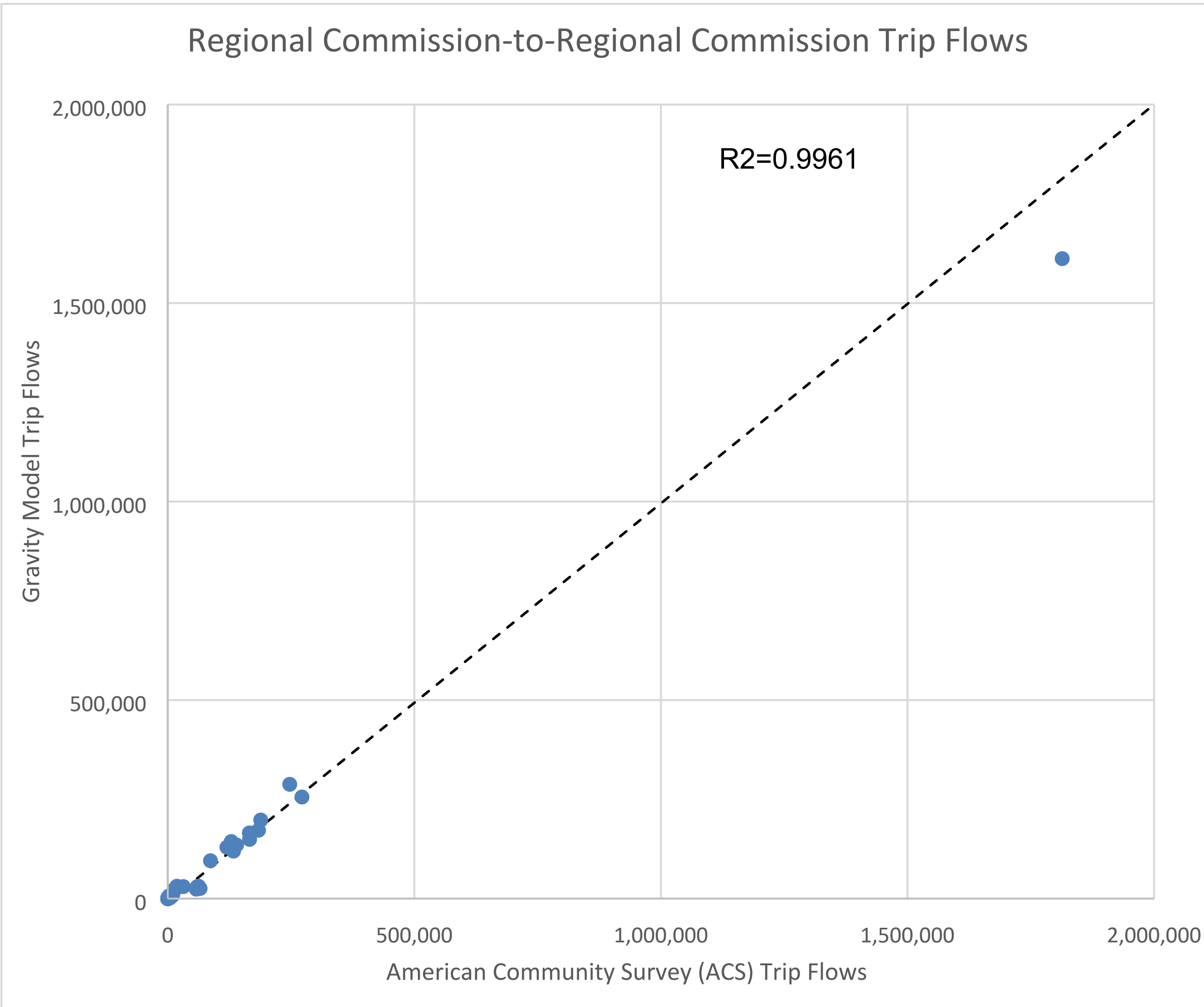
Figure 8-1: District to District Work Trips between Model and ACS (Greater than 2,000 trips)



Data Source: 2009-2013 Five-Year American Community Survey (ACS)

Another way to look at the comparison is to plot the data on a scatter plot. The scatter plot shows the correlation between two data variables and indicates how well one data variable explains the other. Figure 8-2 shows the scatter plot using the flow between the individual district to district pairs based on the ACS data and based on the model. The R squared is 0.99, meaning the model district flows explained the variation in the survey district flow well.

Figure 8-2: Comparison of Regional Commission Work Flows (ACS Data)



Data Source: ACS 2009-2013 County to County work flow data

8.3 MODE CHOICE

The mode choice model was calibrated by adjusting the constant coefficients in the logit formula. The utility values calculated were used to allocate the share of modes between each O-D trip pair. The mode choice model was validated at both the aggregated level and at the individual route level. At the aggregated level, the mode share results for travel were compared with the American Travel Survey (ATS). The ATS collects information about long-distance travel of persons living in the United States. The information was used to identify characteristics of current users of the nation's transportation system. Table 8-7 shows the comparison between the model results and ATS data. According to ATS, the vast majority of travelers in Georgia use automobile as their prime choice for transportation. Less than 2 percent of travelers relied on the non-highway transportation system.

Table 8-7: Mode Share Comparison

Mode	Model	1995 ATS
Air	1.2%	1.3%
Train	0.1%	0.2%
Auto & Other	98.7%	98.5%

At the individual route level, the model results were compared with FAA original-destination survey. This data includes a 10 percent sample of airline tickets from reporting carriers collected by the Office of Airline Information of the Bureau of Transportation Statistics. Data includes origin, destination, and other itinerary details of passengers transported. This database is used to determine air traffic patterns, air carrier market shares, and passenger flows. Table 8-8 shows the comparison between the model results and the survey by individual service route.

Table 8-8: Air Travel Model Calibration Results

	Daily Trips		
Route	**Observed**	**Model**	**% Difference**
Atlanta-Nashville	351	146	-58%
Atlanta-Birmingham	72	39	-46%
Atlanta-Chattanooga	22	251	1041%
Atlanta-Charlotte	671	393	-41%
Atlanta-Augusta	35	86	146%
Atlanta-Charleston	314	123	-61%
Atlanta-Savannah	220	2	-99%
Atlanta-Brunswick	88	22	-75%
Atlanta-Jacksonville	693	748	8%
Atlanta-Valdosta	23	37	61%
Atlanta-Albany	14	17	21%
Atlanta-Tallahassee	157	76	-52%
Atlanta-Greenville	50	37	-26%
Atlanta-Columbus	6	32	433%
Atlanta-Macon	0	0	0%
Atlanta-Montgomery	33	6	-82%
Atlanta-Knoxville	99	36	-64%
Atlanta-Columbia	96	57	-41%
Atlanta-Orlando	1,195	1,632	37%
Atlanta-Tampa	1,041	1,383	33%
Total	**5,180**	**5,123**	**-1%**

Data Source: FAA Origin and Destination Survey (DB1B) ,2015

The conventional rail mode represents the Amtrak service. The boarding information was collected from both the Amtrak fact sheets and the origin-destination survey. The mode results were compared with the survey data in Table 8-9.

Table 8-9: Amtrak Rail Model Calibration Results

Route	Observed	Model	% Difference
Crescent	129	42	-67%
Palmetto	14	6	-58%
Silver	60	29	-52%
Silver star	22	28	30%
Total	**225**	**105**	**-53%**

Data Source: AMTRAK 2015 Factsheet

Currently, there is no High-Speed Rail (HSR) facility in Georgia. This mode component has not been calibrated and is left as a place holder for future model improvement.

The output from the mode choice model is person trips for each mode of transportation. The automobile person trips are converted into vehicle trips which then are assigned to the highway network. This conversion is achieved by applying auto occupancy rates, which reflect the degree of carpooling for each trip type. These factors were developed from the 2009 NHTS. The auto occupancy rates used in the Georgia Statewide Model are listed in Table 8-10 along with those found in other statewide models.

Table 8-10: Auto Occupancy Rate

	Short Trips			Long Trips		
Trip Type	GSTDM	Other Statewide Models*		GSTDM	Other Statewide Models*	
		Low	High		Low	High
HBW	1.1	1.10	1.19	1.5	1.19	2.43
HBO	1.5	1.54	1.78	2.0	1.31	2.69
NHB	1.5	1.56	1.79	2.0	1.31	2.69
IE	2.0	1.50	2.26	2.0	1.50	2.55

** Values from Validation and Sensitivity Considerations for Statewide Model*
NCHRP Project 836-B Task 91, September 2010

8.4 TRAFFIC ASSIGNMENT

The assignment model was calibrated so that the base year model volumes reasonably replicate observed 2015 ground traffic counts. The base year model volumes were checked using a variety of measures such as the percent error of assigned volumes compared with ground traffic counts, the screenline analysis, and the reasonableness of the model's Vehicle-

Miles Traveled (VMT) statistics. Model volumes were validated against traffic counts at several levels – regional, corridor, and individual links. Regional evaluations include VMT, percent Root Mean Squared Error (RMSE), and R-Squared calculations. Corridor evaluations primarily include screenline comparisons. Because the GSTDM will be used to provide external volumes for the GDOT MPO models, the model volumes were also validated at the MPO boundaries. In addition, traffic flows crossing the state line were checked for reasonableness. Nationally recognized maximum desirable deviation standards are applied to analyze model performance at the link level. These include FHWA's "Calibration and Adjustment of System Planning Models," 1990 and the NCHRP Report 365: "Travel Estimation Techniques for Urban Planning," 1998.

8.4.1 Screenlines

Screenlines are defined by man-made or natural geographic barriers such as railroads, creeks, and rivers. The screenlines are designed to measure the systematic travel across the region and to ensure that the model has reasonably captured those flows. Figure 8-3 exhibits the locations of the screenlines used in the validation process. Similarly, major roadways crossing the existing MPO boundary were also examined. Figure 8-4 shows the existing MPO areas covered in the model. The MPO area shown for Atlanta reflects the 20-county MPO, which is included in the ARC regional travel demand model at the time of the model update.

Figure 8-3: GSTDM Screenline Locations

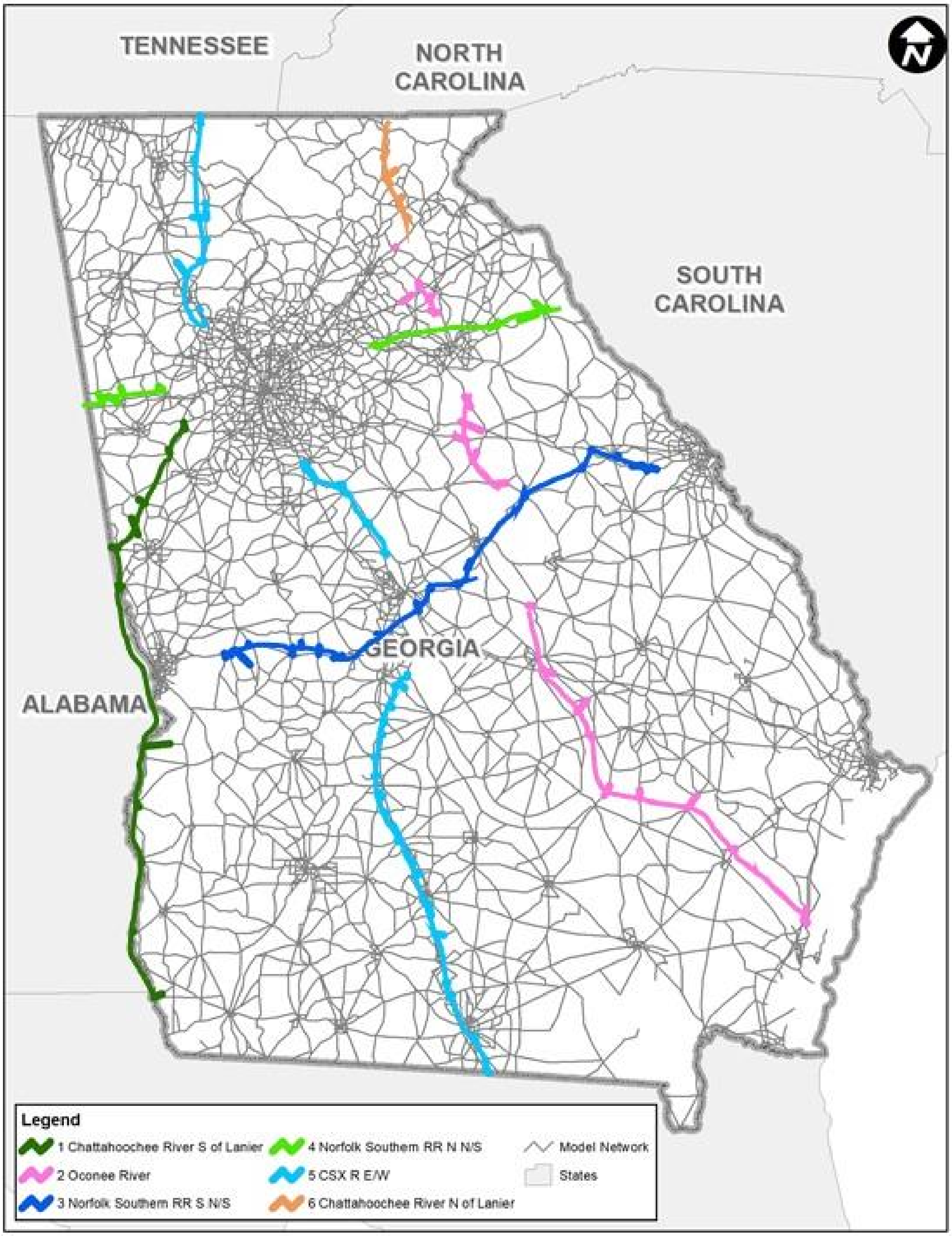


Figure 8-4: GSTDM MPO Boundaries

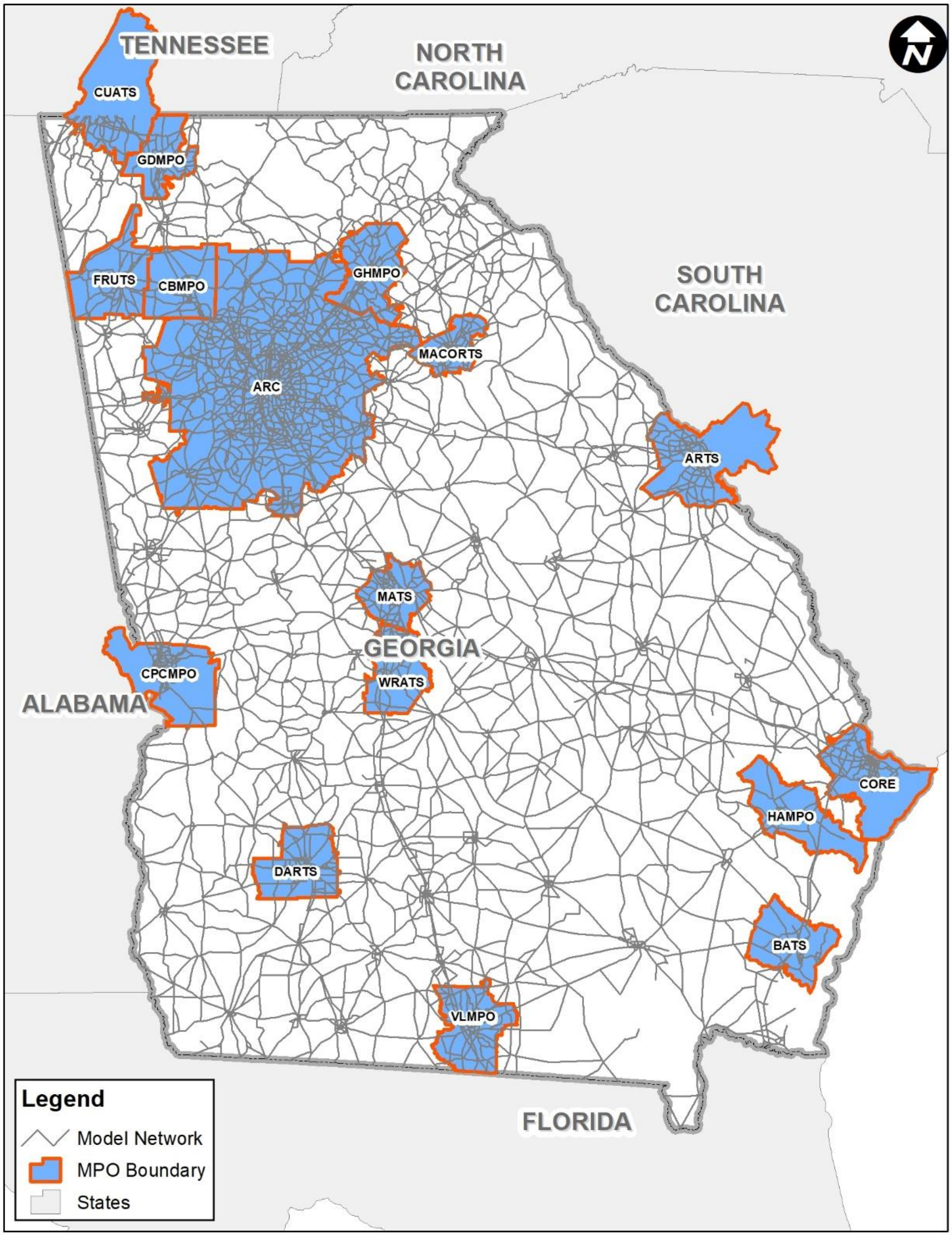


Table 8-11 to Table 8-13 list the summary of travel volume analysis for the screenlines, MPO boundaries, and state line boundaries. Based on the magnitude of observed traffic flows, a maximum desired deviation limit was calculated. The maximum desirable deviation sets the suggested limits for the volume difference and reflects the range within which model results are considered reasonable. All the model volumes for the analysis are within the acceptable range of observed traffic volumes. In most cases, the largest differences between the model and observed counts occur on the lesser traveled facilities or facilities located within dense areas where a detailed roadway system is not well represented in the model network. This is expected since the GSTDM is designed to capture higher-volume corridors serving major intercity travel and the transportation network is limited in detail at the local level.

$$MDD = (0.42076)\left(\frac{C}{25,000}\right)^{-0.3811}$$

Where MDD is the maximum desired deviation and c is the value of the observed traffic count.

Table 8-11: Screenline Summary

Screenline Name	Total Counts	Total Volume	Volume /Count	% Deviation	Maximum Desirable Deviation
1 Chattahoochee River S of Lanier	55,130	71,386	1.29	29%	±31%
2 Oconee River	244,750	232,193	0.95	-5%	±18%
3 Norfolk Southern RR S N/S	`144,800	141,404	0.98	-2%	±22%
4 Norfolk Southern RR N N/S	64,190	61,599	0.96	-4%	±29%
5 CSX RR E/W	374,120	354,602	0.95	-5%	±15%
6 Chattahoochee River N of Lanier	32,950	27,666	0.84	-16%	±38%

Data Source: 2015 GDOT Counts

Table 8-12: MPO Boundary Summary

MPO Name	Total Counts	Total Volume	Volume/Count	% Deviation	Maximum Desirable Deviation
1 Albany	55,170	51,130	0.93	-7%	± 31%
2 Athens	115,550	105,360	0.91	-9%	23%
3 Atlanta	650,300	639,720	0.98	-2%	12%
4 Augusta	205,510	165,510	0.81	-19%	19%

MPO Name	Total Counts	Total Volume	Volume/Count	% Deviation	Maximum Desirable Deviation
5 Brunswick	120,770	122,070	1.01	1%	23%
6 Cartersville	316,820	299,010	0.94	-6%	16%
7 Columbus	121,420	134,660	1.11	11%	23%
8 Dalton	196,360	213,830	1.09	9%	19%
9 Gainesville	167,540	161,320	0.96	-4%	20%
10 Hinesville	141,950	137,830	0.97	-3%	22%
11 Macon	216,040	217,160	1.01	1%	18%
12 Rome	64,450	50,920	0.79	-21%	29%
13 Savannah	231,230	204,220	0.88	-12%	18%
14 Valdosta	147,220	142,660	0.97	-3%	21%
15 Warner Robins	195,300	176,240	0.90	-10%	19%

Data Source: 2015 GDOT Counts

Table 8-13: State Line Summary

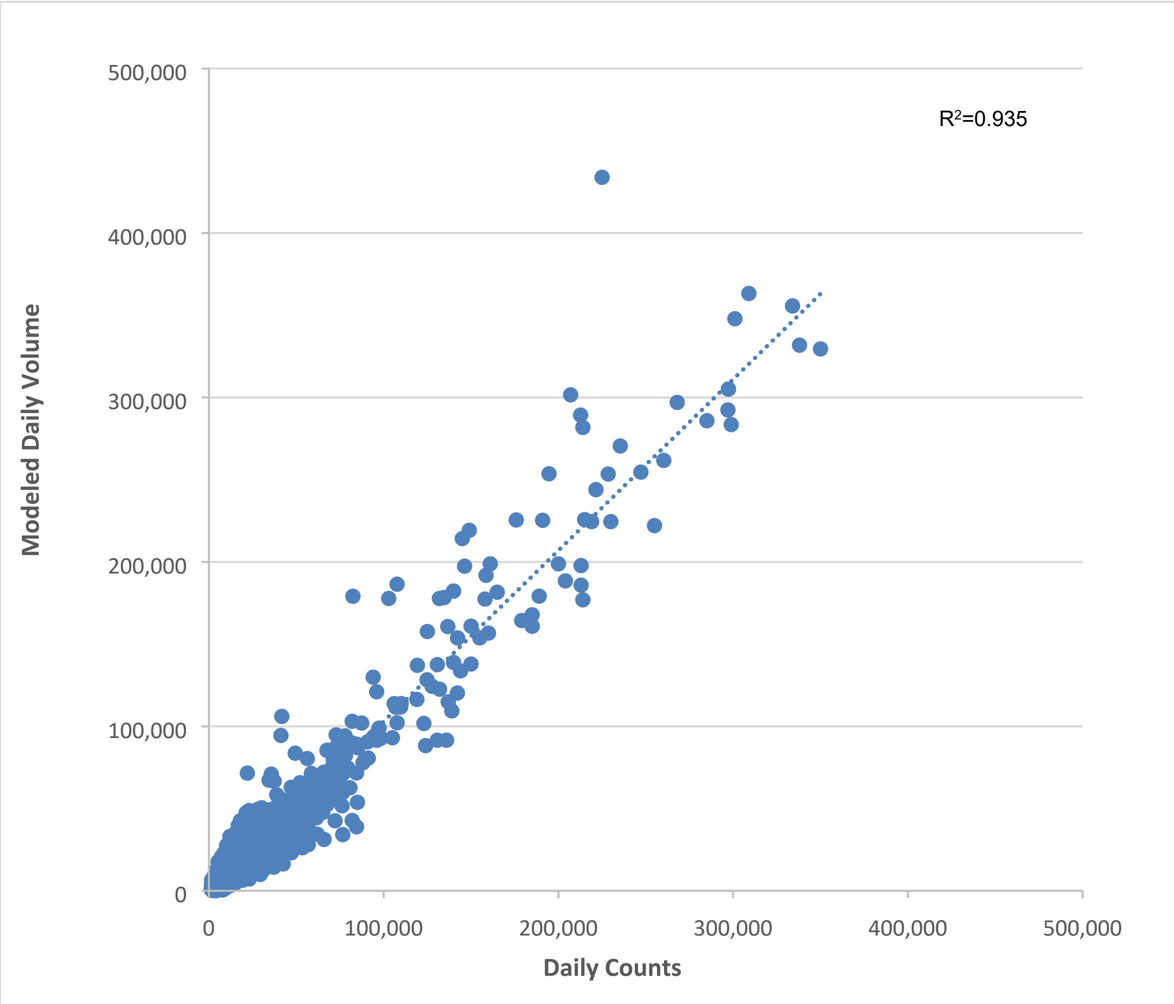
Stateline Name	Total Counts	Total Volume	Volume/Count	% Deviation	Maximum Desirable Deviation
1 North	274,930	237,576	0.86	-14%	±17%
2 East	176,520	163,152	0.92	-8%	±20%
3 South	129,270	124,578	0.96	-4%	±22%
4 West	143,900	122,900	0.85	-15%	±22%

Data Source: 2015 GDOT counts

8.4.2 Link Volumes

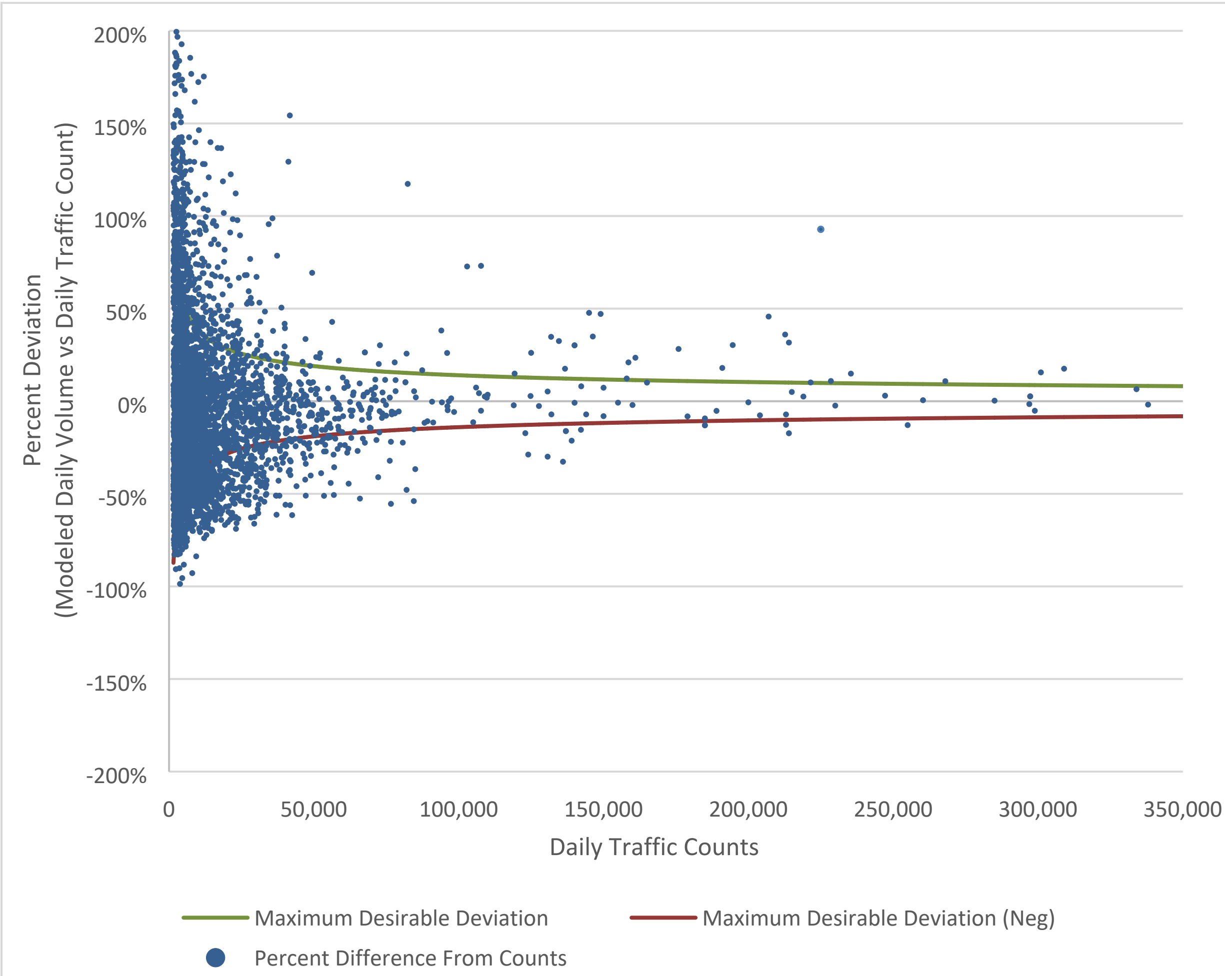
The validation was also performed on the individual network links using a scatter plot that depicts the relationship between link traffic counts and modeled volumes. Figure 8-5 shows the relationship between link traffic and observed traffic counts. The graphic indicates that the majority of modeled volumes are consistent with the traffic counts. It should be noted that it is normal to have outliers, both high and low because the model network is only an abstract representation of the existing highway system, omitting many local roadways. In addition, errors in traffic counts are also common. The R^2 value of 0.935 indicates that the model volumes explained 93.5 percent of the variation in the ground traffic pattern, thus the model is replicating base year travel patterns reasonably well.

Figure 8-5: Link Volume Scatter Plot



Comparing the assigned link volume deviation against the maximum desirable deviation can also reveal the model's performance at the individual link level. As discussed earlier, the higher the existing link traffic count, the smaller the maximum desired deviation allowed on that link. Ideally, models should be able to replicate traffic volumes on higher facilities more accurately than those on lower facilities. Therefore, how the model assigns trips on different facilities is another indicator on how well the model is validated and calibrated. Figure 8-6 shows the comparison of the maximum desired deviation curve and the model assigned volumes. The deviation of link volumes decreases as link traffic counts increase. As expected, the model performs better on higher volume facilities, usually the key corridors in the region. This ensures that the statewide model provides reasonable forecasts for long-distance intercity travel.

Figure 8-6: Link Volume Maximum Desired Deviation Scatter Plot



The percent RMSE by volume group can provide more detailed information on how each volume group performs. Typically, the percent RMSE statistics should generally decrease as traffic volume increases. All highway links with traffic counts were grouped into seven volume groups from less than 5,000 daily vehicles to over 50,000 daily vehicles. The comparisons were also made based on the link area type as well as the results from other peer statewide models. Table 8-14 shows that the model consistently performs better in the rural areas which it was designed to do. This is also expected since the major intercity flows heavily use the rural corridors. Inside the urban areas, the model is constrained by the limited number of zones, roadway facilities, as well as the abstraction of centroid connector locations. Because of this, the MPO models should be used instead when performing detailed evaluation of travel conditions and patterns within the MPO areas. The percent RMSE results are also compared with those of peer statewide models. The results are well within other statewide models' experiences.

Table 8-14: Link Volume % RMSE

Volume Group	Number of Count Locations	% RSME GSTDM Total	Other Statewide Models* Low	Other Statewide Models* High
< 5,000	1,340	61	22	290
5,000-10,000	888	45	22	114
10,000-20,000	751	40	22	86
20,000-30,000	357	35	19	57
30,000-40,000	188	29	14	49
40,000-50,000	112	28	12	36
> 50,000	234	25	5	41
Total	3,870	48	33	90

** Values from Validation and Sensitivity Considerations for Statewide Model*
NCHRP Project 836-B Task 91, September 2010

Table 8-14 also shows that the overall percent RMSE is relatively high for the lower level of traffic count volume groups. The modeled volumes on these low-volume facilities are highly sensitive to the location of the centroid connector which is the aggregation of local street system that facilitates trips from zones to adjacent highway network. On the other hand, modeled volumes on the high-volume facilities are less influenced by the centroid connector location. Therefore, it is expected that the low-volume facilities tend to have higher percent RMSEs. Over 50 percent of the count locations in the model network belong to the volume group of 5,000 and less and 66 percent of the count locations have volumes of 10,000 or less. The large concentration of links in the low-volume groups can overweight the average percent RMSE. Thus, the overall percent RMSE is heavily relied on the distribution of the count stations across all volume groups. Table 8-15 shows the distribution of the traffic count stations in the statewide model by facility type, area type, as well as the volume group.

Table 8-15: Number of Traffic Count Locations by Volume Group, Facility Type, and Area Type

Facility	Traffic Counts - Volume Group							Grand Total	% of Total
	<5,000	5,000-10,000	10,000-20,000	20,000-30,000	30,000-40,000	40,000-50,000	>50,000		
Interstate	0	0	11	40	37	63	195	346	9%
Freeway or Expressway	0	5	11	9	13	5	12	55	1%
Principal Arterial	324	436	477	254	117	38	26	1,672	43%
Minor Arterial	675	374	235	51	20	6	1	1,362	35%
Major Collector	336	71	17	3	1	0	0	428	11%
Minor Collector	5	2	0	0	0	0	0	7	0%
Total	**1,340**	**888**	**751**	**357**	**188**	**112**	**234**	**3,870**	**69%**

The model assignment was validated by highway functional class as well. Table 8-16 shows the model VMT on links with traffic counts. The better match of the model VMT and the count VMT indicates better model performance. This table confirms that the GSTDM performed well in estimating traffic volumes on the higher facilities such as interstates and principal and minor arterials. It is reasonable to see that the model does not perform as well on lower volume facilities such as collectors and local roads due to limitations of the model discussed earlier. This pattern is also consistent with Table 3-6 in the Highway Network chapter, which shows the model represents higher functional classification facilities well. The VMT are also compared against data reported in GDOT 445 Report. Table 8-16 shows that the model is performing well for higher volume facilities.

Table 8-16: VMT Comparison with GDOT 445 Report

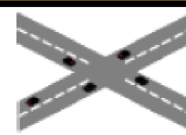
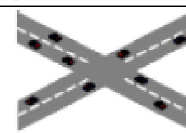
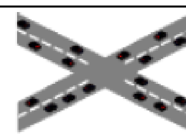
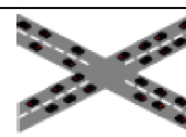
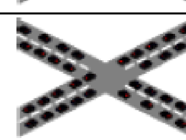
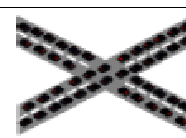
Highway Facility	GDOT 445 Report	Model	Difference
Interstate and Freeway	93,704,759	92,777,470	-1%
Principal Arterial	61,501,754	55,268,696	-10%
Minor Arterial	61,445,957	49,165,908	-20%
Major Collector	30,073,480	13,726,736	-54%
Minor Collector	2,708,172	565,421	-79%

Data Source: GDOT 445 Report

8.5 BASE YEAR LEVEL OF SERVICE

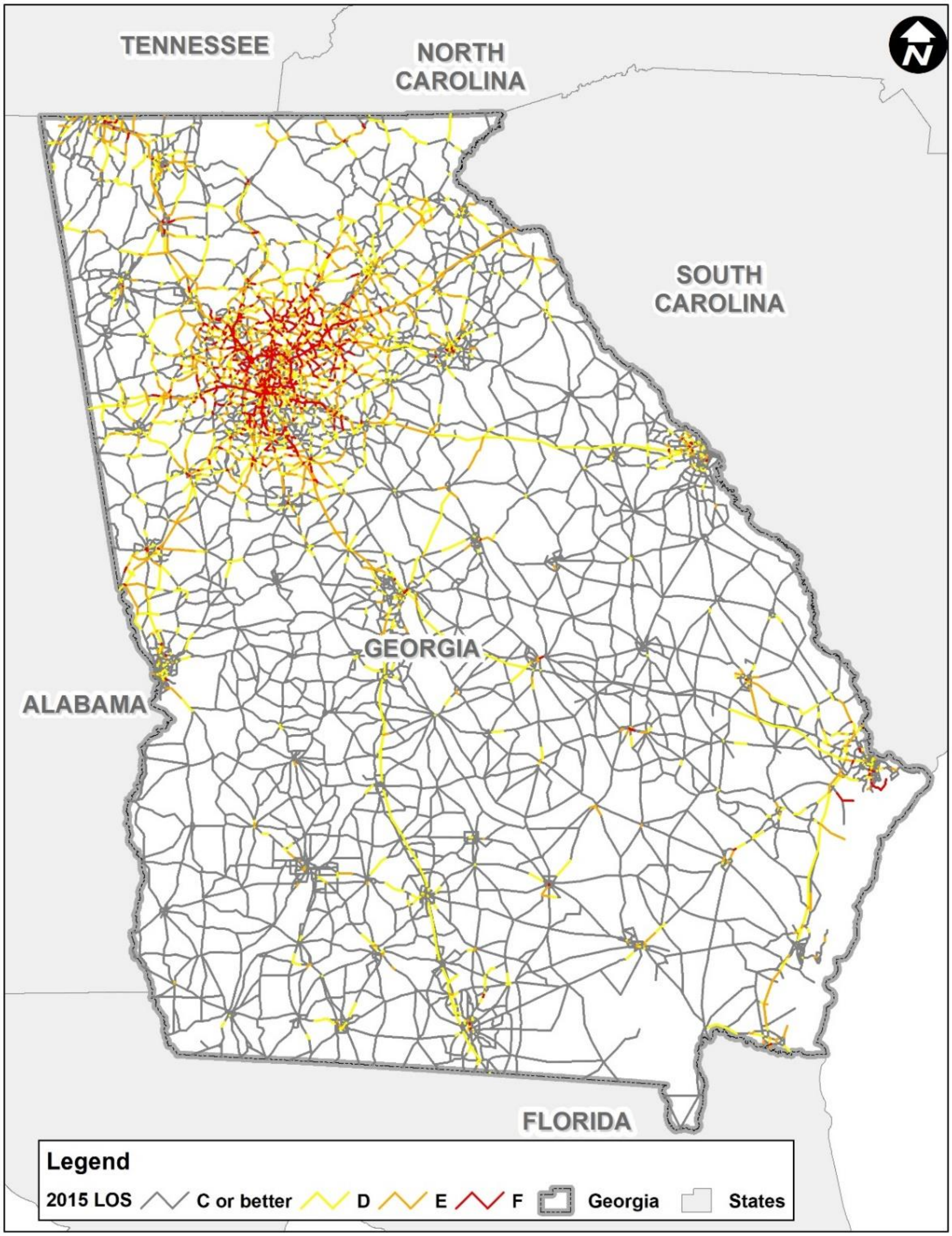
The purpose of TDM development is to assist in the evaluation of future travel conditions and deficiencies in the study area. Besides the traffic volumes, a key output from the TDM is the daily volume-to-capacity ratio for each roadway segment. Each volume-to-capacity ratio corresponds to a level-of-service (LOS) based on accepted methodologies. LOS is a qualitative measure of traffic flow describing prevailing operational conditions. Six LOS are defined by the FHWA in the Highway Capacity Manual for use in evaluating roadway operating conditions. They are given letter designations from A to F, with LOS A representing the best operating conditions and F the worst. A facility may operate at a range of levels of service depending upon time of day, day of week, or period of the year. A qualitative description and depiction of the different levels of service is provided in Figure 8-7.

Figure 8-7: Level of Service Description and Depiction

Description	Depiction
LOS A – Drivers perceive little or no delay and easily progress along a corridor.	
LOS B – Drivers experience some delay but generally driving conditions are favorable.	
LOS C – Travel speeds are slightly lower than the posted speed with noticeable delay in intersection areas.	
LOS D – Travel speeds are well below the posted speed with few opportunities to pass and considerable intersection delay.	
LOS E – The facility is operating at capacity and there are virtually no useable gaps in the traffic.	
LOS F – More traffic desires to use a particular facility than it is designed to handle resulting in extreme delays.	

The 2015 base year GSTDM LOS is presented in Figure 8-8.

Figure 8-8: 2015 Base Year Level-of-Service Map



9. TIME-OF-DAY ASSIGNMENT

One of the peer review recommendations was to develop a time-of-day (TOD) assignment model for the GSTDM. The objective for TOD assignment was to process the GSTDM's daily model outputs to obtain peak period traffic volumes and travel times. For certain transportation investment projects, it is beneficial to understand the impacts of traffic and evaluate projects performance during peak periods.

GDOT hourly traffic counts at permanent stations were analyzed to assess the temporal distribution of autos and trucks within Georgia. The permanent count stations provide a reasonable coverage of the area types and different facility types used in GSTDM. It was observed that there is considerable variation in the TOD distribution pattern between urban and rural areas due to different land use and travel patterns. Therefore, it was recommended that the daily assignment remain the standard approach for GSTDM. However, to enhance the model, the TOD assignment model for AM and PM peak periods were developed to provide additional information for the projects that require assessment in the peak periods. The TOD assignment model was developed as a post-processor to the daily model and require running the daily model first.

GSTDM, being a daily model, uses daily roadway capacities for assignment. For the TOD assignments, peak-period capacities are required. To determine peak-period capacities, hourly capacities were first estimated based on the daily capacities and then converted to peak-period capacities using appropriate factors. Hourly capacities and speeds vary by area type and facility type. The area type definition and the corresponding speeds and daily capacities used in GSTDM were also reviewed and revised as part of the effort for the TOD model development. See Chapter 3 for additional information on the development of capacities. At the time of development of time-of-day module, GSTDM had a base year of 2010 and therefore all the data used was collected for 2010 or year close to that if 2010 data was not available.

The approach used the following steps in developing the TOD model:

- Define the morning (AM) and afternoon (PM) peak periods;
- Develop the time-of-day factors for passenger cars and freight vehicles;
- Estimate peak-period capacities;
- Develop scripts and a standalone application for TOD assignments; and
- Check model output reasonableness and summarize initial observations.

Each step is described in the following subsections.

9.1 DEFINE THE MORNING (AM) AND AFTERNOON (PM) PEAK PERIODS

9.1.1 Data Sources

In order to define the duration and the time periods for AM and PM peak periods, the diurnal distribution of auto and truck traffic counts at various locations within Georgia were observed. Because diurnal distribution of traffic counts was not available for year 2010, 2012 GDOT traffic counts data was chosen to help develop distribution factors. The 2012 distribution factors were assumed to apply for the 2015 base year as well.

The data included 2012 traffic counts of all the vehicles combined, by each hour. In order to simplify data processing while ensuring sufficient data was available to assess the distribution patterns for the entire state, serval criteria were used during the process. Some of these criteria required additional data sources. The criteria along with the data sources are mentioned below:

1. **Permanent stations selected**
   Data source: 2012 GDOT traffic counts

   Only permanent traffic count stations were selected. The permanent stations provided a good coverage of different area types and facility types used in GSTDM.

2. **Facilities with functional classification of minor arterials and above**
   Data source: 2012 GDOT traffic counts

   Permanent count stations that exist on local roads and collectors were excluded as GSTDM focuses the roadway facilities with the functional classification of minor arterials and above.

3. **Day selected - May 3, 2012 (Thursday)**
   Data source: GDOT 2010 traffic factors

   2010 monthly and daily factors were taken from GDOT as shown in Appendix Table A1 and Table A2, respectively. Based on these tables, May shows the least variation in monthly factors across different facilities and Thursday shows the least variation in daily factors across different facilities. Therefore, diurnal distribution of traffic counts was selected for the first Thursday of May 2012.

4. **Truck percentages used to estimate truck and auto counts**
   Data source: 2011 Vehicle Classification by Functional Classification and Hour

The 2012 GDOT traffic count data comprises all vehicles and does not provide truck and auto counts separately. Understanding that trucks in general have different diurnal distribution than autos, the truck percentage was estimated and applied to the total counts to estimate truck and auto counts. To estimate the truck percentage, GDOT's Vehicle Classification by Functional Classification and Hour, was used. It provides percentage share of 13 vehicle types for each hour by different facility types. The data was not available for 2010, so it was taken from 2011. The resulting percentages of trucks and commercial vehicles by hour and by facility type are shown in Table 9-1.

Table 9-1: Truck & Commercial Vehicle Percentage by Functional Class. & Hour

	MEDIUM AND HEAVY TRUCK %									COMMERCIAL VEHICLES %								
HOUR	Rural Principal Arterial - Interstate	Rural Principal Arterial - Other	Rural Minor Arterial	Rural Major Collector	Urban Principal Arterial - Interstate	Urban Principal Arterial - Other Freeways/Expressways	Urban Principal Arterial - Other	Urban Minor Arterial	Urban Collector	Rural Principal Arterial - Interstate	Rural Principal Arterial - Other	Rural Minor Arterial	Rural Major Collector	Urban Principal Arterial - Interstate	Urban Principal Arterial - Other Freeways/Expressways	Urban Principal Arterial - Other	Urban Minor Arterial	Urban Collector
1	36.0	14.2	6.6	4.2	10.8	4.9	2.6	1.7	0.4	2.4	2.4	2.1	2.8	1.8	1.4	1.4	1.3	1.1
2	41.5	19.7	9.8	6.6	14.7	7.0	4.0	2.2	0.6	2.6	3.0	2.6	3.0	2.2	1.9	1.7	1.6	1.3
3	46.6	24.4	11.5	9.4	17.5	9.3	5.2	3.0	0.8	2.7	3.6	2.8	3.5	2.6	2.5	2.1	2.0	1.4
4	49.6	27.9	12.8	12.6	18.8	10.4	6.7	3.8	0.9	2.9	4.6	3.7	4.7	3.0	2.9	2.6	2.5	1.5
5	45.6	20.6	10.1	9.0	17.1	8.4	6.2	3.8	0.9	3.2	4.6	3.7	4.7	3.6	3.3	3.1	3.1	2.0
6	32.3	11.8	5.4	5.3	9.6	4.7	3.8	2.9	1.0	3.6	4.2	3.6	4.4	3.4	2.9	3.1	3.1	2.6
7	23.0	8.3	4.2	4.0	5.8	3.0	2.7	2.2	1.7	4.0	4.6	4.1	4.1	3.3	2.7	3.2	3.2	3.1
8	18.0	6.2	3.6	3.3	4.6	2.7	2.2	1.7	1.2	3.5	3.9	3.7	3.9	2.7	2.5	2.8	2.6	2.5
9	18.7	7.7	4.9	3.4	5.6	3.4	2.7	1.8	1.2	3.5	4.5	4.6	4.5	3.0	2.8	3.2	3.1	2.8
10	18.8	8.4	5.8	3.4	6.8	4.2	2.9	2.0	1.1	3.4	4.6	5.0	4.5	3.3	3.1	3.4	3.5	3.1
11	17.9	8.0	5.7	3.1	7.1	4.5	2.8	1.9	1.0	3.0	4.2	4.5	4.1	3.2	3.1	3.1	3.2	2.7
12	17.5	7.6	5.4	2.8	7.0	4.2	2.5	1.7	0.9	2.8	3.9	4.2	3.9	3.1	3.0	2.9	2.9	2.5
13	17.2	7.0	4.7	2.5	6.6	3.9	2.2	1.4	0.8	2.8	3.7	3.9	3.6	3.0	2.9	2.7	2.6	2.2
14	16.5	6.9	4.6	2.5	6.3	3.8	2.2	1.5	0.8	2.8	3.7	3.8	3.5	2.9	2.8	2.6	2.6	2.1
15	15.6	6.5	4.0	2.8	5.8	3.4	2.1	1.4	1.1	2.7	3.5	3.7	3.7	2.8	2.7	2.6	2.5	2.1
16	14.8	5.7	3.4	2.8	5.2	3.0	1.8	1.3	0.9	2.7	3.3	3.4	3.3	2.6	2.4	2.4	2.3	2.1
17	14.2	5.0	3.0	2.0	4.5	2.4	1.6	1.1	0.7	2.6	3.1	3.1	3.2	2.3	2.0	2.2	2.1	1.7
18	13.9	4.2	2.4	1.5	4.0	2.0	1.2	0.8	0.4	2.5	2.7	2.8	2.8	2.0	1.7	1.9	1.7	1.4
19	15.6	4.6	2.5	1.4	4.5	2.0	1.2	0.8	0.4	2.6	2.7	2.7	2.6	1.9	1.6	1.7	1.6	1.5
20	17.7	5.1	2.6	1.4	5.2	2.2	1.2	0.8	0.3	2.5	2.5	2.4	2.5	1.8	1.5	1.5	1.5	1.5
21	19.7	5.7	2.7	1.4	5.7	2.4	1.2	0.8	0.4	2.4	2.3	2.2	2.3	1.7	1.5	1.4	1.4	1.4
22	21.9	6.4	2.8	1.5	5.9	2.5	1.3	0.8	0.3	2.4	2.2	1.9	2.2	1.5	1.3	1.3	1.2	1.2
23	25.5	7.8	3.2	1.8	6.7	2.7	1.5	1.0	0.4	2.4	2.2	1.8	2.1	1.5	1.2	1.2	1.2	1.0
24	30.2	10.2	4.0	2.5	8.1	3.4	1.9	1.3	0.4	2.3	2.3	1.9	2.2	1.5	1.3	1.2	1.2	0.9
Daily	19.2	6.9	4.0	2.6	6.2	3.3	2.1	1.4	0.8	2.8	3.5	3.5	3.4	2.5	2.3	2.4	2.3	2.0

9.1.2 Methodology and Results

There were 28 of the permanent stations with traffic counts missing for the selected day of May 3, 2012. In addition, 27 stations existed on local roads and collectors. These stations were eliminated from further analysis, yielding 172 remaining permanent count stations.

The GDOT traffic counts consisted of hourly counts of all types of vehicles. Separate hourly counts for auto and truck were estimated using the truck percentage from 2011 Vehicle Classifications by Functional Classification and Hour (Table 9-1). The diurnal distribution of truck counts showed that the peak hour varied considerably with some count stations showing a single-peaking hour that may also occur in the midday. Therefore, truck counts were not considered in estimating the AM and the PM peak periods.

The diurnal distribution of auto counts was observed, and the three-hour period that had highest traffic counts between 6 a.m. and 11 a.m. was estimated for the AM period, and the three-hour period that had highest traffic counts between 2 p.m. and 7 p.m. was estimated for the PM period. In addition, the highest hour was also estimated for each of the two time periods. The results are summarized below:

- The highest three-hour AM peak period is 7 a.m. to 10 a.m.;
- The hour with highest traffic counts in the AM is 7 a.m.to 8 a.m.;
- The highest three-hour PM peak period is 3 p.m. to 6 p.m.; and
- The hour with highest traffic counts in the PM is 5 p.m. to 6 p.m.

The results were combined in order to determine the AM and PM peak periods. In addition, the hour before and the one after the highest hour were also included. Therefore, the recommended peak periods include four hours in each AM and PM peak period and are mentioned below. The recommended periods are consistent with the AM and PM peak periods used by Atlanta Regional Commission in their regional model.

The recommended peak periods are:

- AM peak period: 6 a.m. to 10 a.m.; and
- PM peak period: 3 p.m. to 7 p.m.

9.2 DEVELOP THE TIME-OF-DAY FACTORS FOR PASSENGERS AND FREIGHT TRIPS

Temporal allocation of the auto and truck vehicle trips was accomplished by applying factors specific to trip purpose and direction to the respective daily trip matrices to derive peak period (AM and PM) trip matrices for traffic assignment. The factors are applied to daily trips between the mode choice and the assignment steps. The mode choice output from GSTDM consists of trip tables by different purposes from the passenger model and freight model. The trip tables are arranged in the following categories as shown in Figure 9-1.

Figure 9-1: Time of Day Trip Tables

Internal to Internal (II)	• No sub-category trips
Short-Distance Internal-Internal (II)	• HBW - Home-based work • HBO – Home-based other • NHB – Non-home-based • Commercial trucks
Internal-external (IE)	• HBW - Home-based work • HBO – Home-based other • NHB – Non home-based • Commercial trucks
Long-Distance (Intercity Trips) Internal-Internal (II)	• HBW - Home-based work • HBO – Home-based other • NHB – Non-home-based
Long-Distance Internal-External (IE)	• Short trips – Externals include census tracts immediately surrounding Georgia • Long trips – Externals include counties, Regional Planning Councils (RPCs) and states outside Georgia
Through Trips	• External to extrenal trips
Freight Trips	• No sub-category trips

Different data sources were explored and used to estimate the TOD factors as described in the next section.

9.2.1 Data Sources

9.2.1.1 2009 National Household Travel Survey (2009 NHTS)

TOD factors for short-distance II and IE and long-distance II auto trips were derived from 2009 National Household Travel Survey (2009 NHTS) data on a production-to-attraction (PA) basis for home-based travel. Factors for non-home-based person trips are derived on an origin-to-destination (O-D basis) and applied to the corresponding O-D trip matrices. The factors were estimated for both long trips (greater than 50 miles) and short trips (less than 50 miles). Table 9-2 and Table 9-3 show production to attraction (P->A) and attraction to production (A->P) TOD factors for long-distance and short-distance trips, respectively.

Table 9-2: TOD Factors for Long Trips

	Volume		Distribution		Final Factors	
	P->A	A->P	P->A	A->P	P->A	A->P
HBW						
AM	29,397	-	54%	0%	26.8%	0.0%
MD	1,059	82	2%	0%	1.0%	0.1%
PM	511	29,700	1%	79%	0.5%	39.5%
NT	23,889	7,811	44%	21%	21.8%	10.4%
Sum	**54,857**	**37,593**	**100%**	**100%**	**50.0%**	**50.0%**
HBO						
AM	21,738	2,108	46%	3%	23.2%	1.4%
MD	9,345	32,316	20%	42%	10.0%	20.8%
PM	7,301	23,023	16%	30%	7.8%	14.8%
NT	8,419	20,286	18%	26%	9.0%	13.0%
Sum	**46,803**	**77,733**	**100%**	**100%**	**50.0%**	**50.0%**
NHB						
AM	48,535	-	29%		14.7%	14.7%
MD	64,889	-	39%		19.6%	19.6%
PM	35,240	-	21%		10.6%	10.6%
NT	16,868	-	10%		5.1%	5.1%
Sum	**165,531**	**-**	**100%**		**50.0%**	**50.0%**

Table 9-3: TOD Factors for Short Trips

	Volume		Distribution		Final Factors	
	P->A	A->P	P->A	A->P	P->A	A->P
HBW						
AM	1,218,151	13,024	72%	1%	35.9%	0.5%
MD	179,723	184,314	11%	14%	5.3%	7.0%
PM	66,399	879,372	4%	67%	2.0%	33.3%
NT	229,995	243,936	14%	18%	6.8%	9.2%
Sum	1,694,269	1,320,646	100%	100%	50.0%	50.0%
HBO						
AM	848,670	197,367	41%	10%	20.6%	5.2%
MD	494,425	507,018	24%	27%	12.0%	13.3%
PM	518,891	703,030	25%	37%	12.6%	18.4%
NT	198,471	503,204	10%	26%	4.8%	13.2%
Sum	2,060,457	1,910,618	100%	100%	50.0%	50.0%
NHB						
AM	930,484	-	17%		8.4%	8.4%
MD	2,576,792	-	46%		23.2%	23.2%
PM	1,572,732	-	28%		14.2%	14.2%
NT	463,301	-	8%		4.2%	4.2%
Sum	**5,543,309**	**-**	**100%**		**50.0%**	**50.0%**

For commercial trucks and for the trip purposes that did not have proper sources to estimate the TOD factors, the factors were borrowed from other purposes as appropriate. Based on this, a summary of the source used in estimating the factors for individual purposes is presented in Table 9-4.

Table 9-4: Data Source for TOD Factors for Auto and Commercial Vehicles

Matrix No	Trip Table	Description	Data Source
1	ganhbw	Short HBW	2009 NHTS short trips
2	ganhbo	Short HBO	2009 NHTS short trips
3	gannhb	Short NHB	2009 NHTS short trips
4	gancom	Short Commercial	2009 NHTS short trips (Same as Short NHB)
5	galhbw	Long HBW	2009 NHTS long trips
6	galhbo	Long HBO	2009 NHTS long trips
7	galnhb	Long NHB	2009 NHTS long trips
8	iehbw	I-E short HBW	2009 NHTS short trips
9	iehbo	I-E short HBO	2009 NHTS short trips
10	ienhb	I-E short NHB	2009 NHTS short trips
11	iecom	I-E commercial	2009 NHTS short trips (Same as long NHB)
12	ielsht	I-E long short trips	2009 NHTS short trips (Same as long NHB)
13	ielfar	I-E long far trips	2009 NHTS long trips
14	ee	E-E	2012 GDOT traffic counts
15	ptaccess	Drive access	2009 NHTS short trips (Same as Short NHB)

9.2.1.2 Year 2012 GDOT Traffic Counts

TOD factors for external-external auto trips and trucks were estimated from GDOT traffic counts at the permanent stations. For the finalized AM and PM periods, the percentage of auto and truck traffic was estimated for each of the selected permanent stations. The results are shown in Table 9-5.

Table 9-5: TOD Factors for External-External Auto and Trucks

	AM	PM
EE Auto	22%	29%
Truck	24%	21%

9.3 ESTIMATE PEAK-PERIOD CAPACITIES

The peak-period capacities were estimated by converting the daily capacity to hourly capacity and then expressing the peak-period capacity, for both AM and PM, as a factor of hourly capacity. The process is described in the following two steps.

9.3.1 Estimating the Hourly Capacity

From 2012 GDOT traffic counts data for 172 permanent stations, diurnal distribution of combined auto and truck traffic counts was analyzed for each station. The counts in each hour were expressed as a fraction of the highest count in a day. The fractions were summed up to estimate the factor to convert the peak-period capacity to the peak hour. The average of all factors was estimated to be **12.5**.

9.3.2 Estimating the Peak-Period Capacity

A similar approach was taken to estimate the factor to convert the peak-hour capacity to the peak-period capacity. The counts in each hour of the four-hour peak periods were expressed as a fraction of the highest hour for that period. The fractions were summed up and the average of all factors was estimated for each period. The conversion factor estimated for AM was 3.2 and that for PM was 3.6. An average of the two factors was used for both the periods, resulting in the peak hour to peak-period capacity conversion factor of **3.4**.

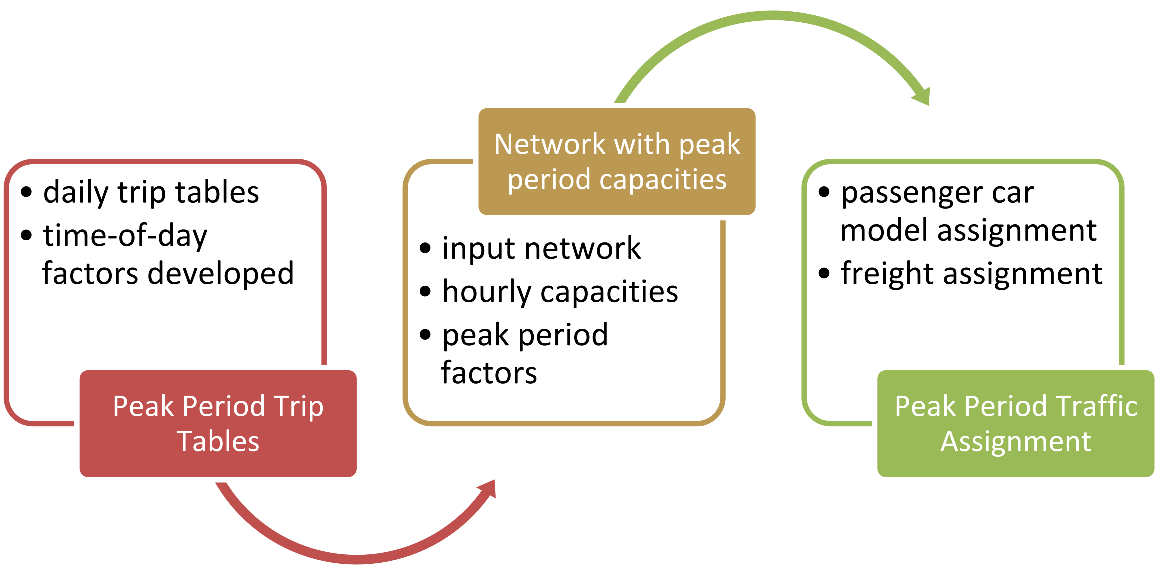
9.4 DEVELOP SCRIPTS AND STANDALONE APPLICATION FOR TOD ASSIGNMENTS

A set of scripts was developed for the AM and PM peak-period assignments. The TOD assignment is an add-on application that will be run after the daily assignment is complete. The process includes three steps:

- First - Creates the AM and the PM peak period trip tables from the daily trip tables using the time-of-day factors developed;
- Second - Updates the network with peak-period capacities; and
- Third - Performs auto and truck assignment for AM and PM peak periods.

Figure 9-2 illustrates the three-step process for the TOD add-on application.

Figure 9-2: TOD Add-On Application Process



9.5 CHECK MODEL OUTPUT REASONABLENESS AND SUMMARIZE INITIAL OBSERVATIONS

A reasonableness check on the TOD factors was performed by running the assignments and comparing the observed and modeled percentage of AM and PM traffic. In order to check the reasonability of TOD factors, the percentage of AM and PM peak period traffic modeled using base year GSTDM was compared with the observed percentage at permanent count stations. The observed and modeled percentage of traffic for all available count stations is shown in Figure 9-3 and Figure 9-4 for AM and PM respectively. The x-axis in the two figures represents the collected volume data at the count stations. The orange line represents the observed volumes and the green line represents the modeled volumes at the corresponding count stations. The average of observed and model percentage is summarized in Table 9-6. As the table shows, the assigned traffic percentage of daily traffic in the AM and PM is close to that observed from GDOT counts.

Figure 9-3: Observed and Modeled Percentage of AM Traffic

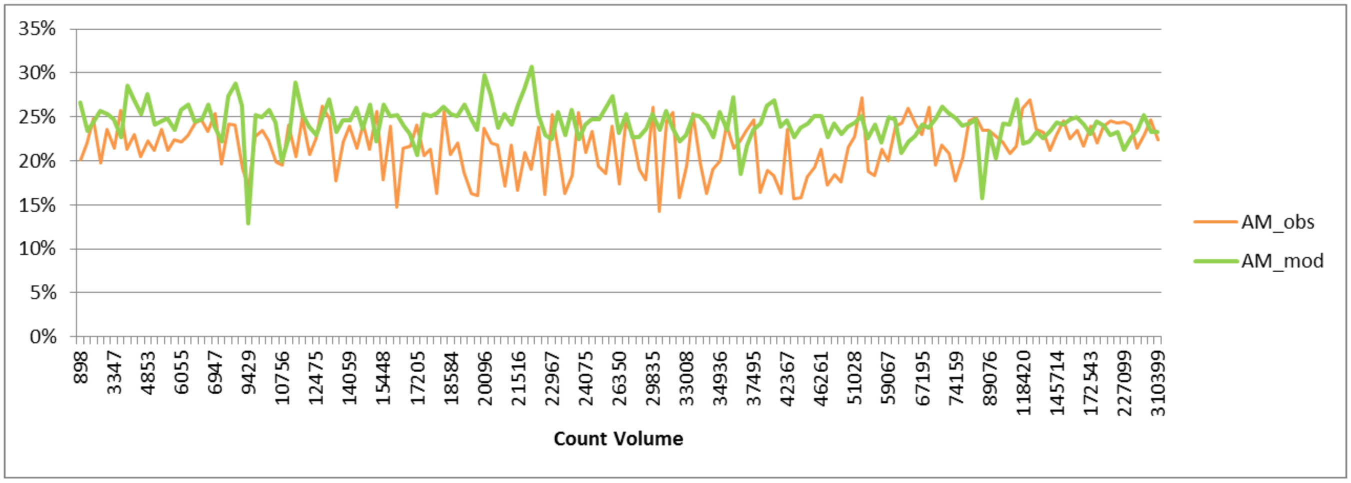


Figure 9-4: Observed and Modeled Percentage of PM Traffic

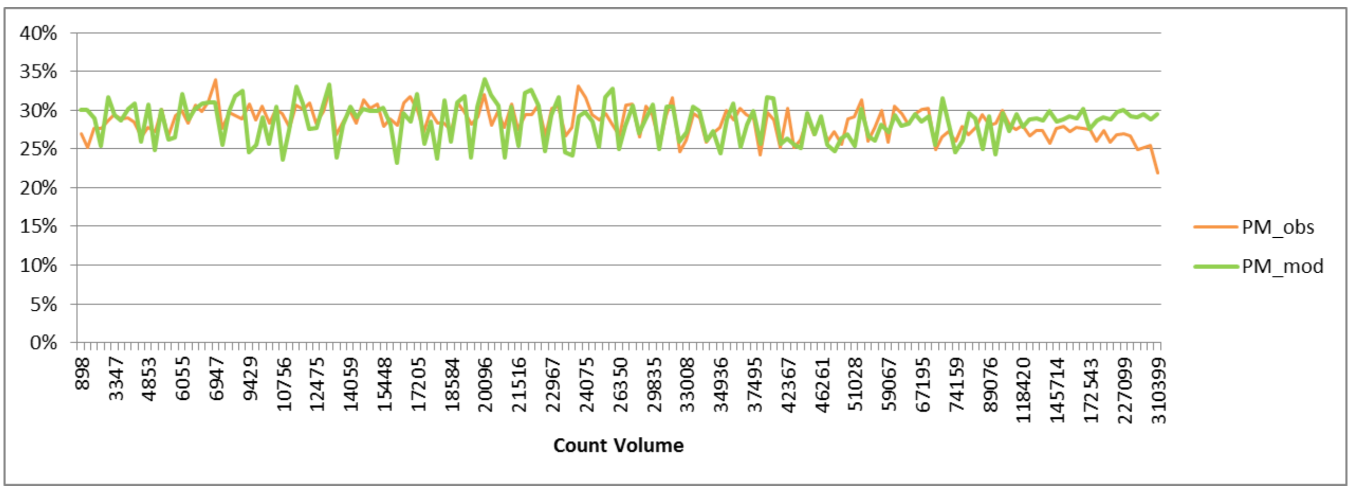


Table 9-6: Observed and Modeled Percentage of Total Daily Traffic

	Observed	Modeled
AM	22%	24%
PM	28%	28%

10. DEVELOPMENT OF FUTURE YEAR MODELS

After the base-year model is calibrated and validated, the model is used to evaluate the traffic conditions in the future. Two future scenarios were developed. The scenarios vary in the future projects they include but are identical in all other aspects.

The future year for the current update is 2050. The following information was updated to develop the future year scenarios:

- Socioeconomic data
- Freight inputs
- Other model inputs

10.1 SOCIOECONOMIC DATA

2050 GSTDM socioeconomic (SE) data was developed based on 2015 GSTDM SE data and 2050 REMI total population forecast. In order to incorporate detailed growth trends in MPO regions, MPO zonal SE data was taken into account when developing 2050 SE estimates for GSTDM TAZs located inside the MPO modeling area.

Population and employment control totals were imposed at the REMI region level (See Table 3-14 for the 43 regions). 2050 REMI region population estimates was used as 2050 GSTDM population control totals. The employment-to-population ratio of 0.4 based on the 2015 SE data was held constant when developing 2050 employment totals.

Household data was developed using estimated 2050 population, assuming the ratio of population per household remains constant in each GSTDM TAZ as of 2015. Employment of four detail categories (agriculture, manufacturing, retail, and service) were developed using estimated 2050 total employment, assuming the distribution in 2015 GSTDM SE data remains constant.

The following sections discuss GSTDM 2050 SE data development processes that are different between non-MPO and MPO regions.

10.1.1 Socioeconomic Data (MPO Regions)

SE data in the 2015 and 2040 ARC models, and 2010 and 2040 non-ARC MPO models, were incorporated in the GSTDM SE data development process to reflect more detail growth trends within MPO areas.

MPO TAZs were first aggregated to GSTDM TAZ level to derive absolute SE changes between 2010 and 2040 (2015 and 2040 for ARC region). These aggregated TAZ data was used to calculate ratios of SE changes in a GSTDM TAZ to the SE changes (both increase and decrease) in the corresponding REMI region. The derived ratios were then applied to the SE changes between 2050 REMI control totals and 2015 GSTDM SE data.

Using the method mentioned above, the increase or decrease trend shown in the MPO models (aggregated to GSTDM TAZ level) can be preserved.

10.1.2 Socioeconomic Data (Non-MPO Region)

Using 2015 GSTDM SE data and 2050 REMI population data, annual growth factors were developed for each REMI region between 2015 and 2050. 2050 GSTDM TAZ population data was calculated by applying respective REMI's annual growth to the 2015 GSTDM TAZ population.

10.2 FREIGHT INPUTS

In addition to the inputs required for the passenger model, the freight component of the model required future year inputs to for the 2050 scenario.

The future year SE data developed for the passenger component was used to grow the base year freight employment for each zone. Each category of freight employment was grown at the same rate as its corresponding passenger employment category, which can be found in Table 5-2. This method keeps employment within the passenger employment control totals. The population and household values from the passenger component are directly used for the freight model.

Similar to SE data, the freight network must be updated parallel to the passenger network. Any expected changes to the rail or other freight-specific links and/or nodes need to be incorporated to create a network that reflects the expected conditions for 2050. Freight network changes are less common than for the passenger component of the network, but there are a number of potential projects that could affect future freight movement. Section 5.3.3 details how the model handles ocean and inland ports, and any future additions or changes to these ports are handled in a similar fashion.

One method described in Section 5.3 to reflect changes to freight movements is adjustment of the freight external trip tables, of which there are three: trucks, rail, and intermodal. This is similar to how the passenger component external tables must be adjusted to reflect future year conditions. E-E, E-I, and I-E freight tables were created for the 2050 scenario. In most cases, SE growth from 2015 to 2050 was used to grow the external trips, but in cases when more precise forecasts exist (such as for large ports, e.g. Jasper Ocean Terminal), those forecasts were used instead. The new external trip values were then factored similarly to the 2015 matrices.

Lastly, the special generator file remained unchanged from 2015, except for the specially considered port changes described earlier where specific forecast information was provided. This methodology was used due to limited information or details for the evolution of the future special generator rates in each applicable zone to determine forecasts with any reliability.

10.3 OTHER MODEL INPUTS

Other inputs for the future model included transit and E-E trip matrices. The transit services were assumed to not change in the future. The E-E trip matrix was forecasted for 2050 by the model process using 2015 E-E trip table and the growth obtained from 2015 and 2050 SE forecasts.

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